THIRD SEMESTER

24MAT301	PROBABILITY DISTRIBUTIONS AND COMPLEX ANALYSIS	L	T	P	J	S	C	Year of Introduction
		3	1	0	0	3	4	2024

Preamble: This course introduces the concept of discrete, continuous probability distributions, testing of hypothesis, complex differentiation and complex integration. The concepts discussed here are widely used in the modeling and analysis of a wide range of physical phenomena and has got application across all branches of engineering. After completing this course, students will acquire the ability to utilize the above concepts for solving mathematical problems more efficiently.

Prerequisite: A basic course in probability distributions and complex numbers.

Course Outcomes: After the completion of the course the student will be able to

CO1	Apply the concept and properties of discrete probability distributions in evaluating the required probabilities (Apply level).
CO2	Apply properties and important models of continuous random variables to analyse suitable random phenomena (Apply level).
CO3	Perform statistical inferences concerning characteristics of a population based on attributes of samples drawn from the population (Apply level).
CO4	Apply Cauchy-Riemann equations and the concept of harmonic functions for solving problems in various engineering domains (Apply level).
CO5	Compute different types of contour integrals using Cauchy's residue theorem (Apply level).

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2			1				1			1
CO2	3	2			1				1			1
CO3	3	2			1				1			1
CO4	3	2			1				1			1
CO5	3	2			1				1			1

Assessment Pattern for Theory component

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-1-0-0	5	15	10	10	40

Total Marks distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: (Discrete probability distributions)

(Text-1: Relevant topics from sections 3.1-3.4, 3.6, 5.1)
Random variables, Discrete random variables, Probability mass function, Cumulative distribution function, Mean and variance, Discrete probability distributions, Binomial distribution, Poisson distribution, Mean and variance of Binomial and Poisson distributions.

MODULE II: (Continuous probability distributions)

(Text-1: Relevant topics from sections 4.1-4.4, 3.6)
Continuous random variables, Cumulative distribution function, Probability density function, Continuous probability distributions, Uniform distribution, Mean and variance of uniform distributions, Normal distribution.

MODULE III: (Test of Hypothesis)

(Text-1: Relevant topics from sections 5.4, 3.6, 5.1,7.2, 8.1, 8.3, 9.1-9.2,9.4)
Population and samples, Sampling distribution of the mean and proportion (for large samples only), Confidence interval for single mean and single proportions (for large samples only). Test of Hypothesis: large sample test for single mean and single proportion, Equality of means, small sample t-tests for single mean of normal population, Equality of means (for independent samples from two normal populations with equal variance).

MODULE IV: (Complex differentiation)

(Text 2: Relevant portions of sections 13.3,13.4)
Circles and disks, half planes, Complex functions, Limit, Continuity and derivatives, Analytic functions, Cauchy-Riemann equations, Laplace equation, Harmonic functions, Harmonic conjugate functions.

MODULE V: (Complex Integration)

(Text 2- Relevant topics from sections 14.1,14.2,14.3,14.4,15.4,16.1,16.2,16.3)
Cauchy’s integral theorem for simply connected domains (without proof), Cauchy’s Integral formula for simply connected domains (without proof), Cauchy’s Integral formula for derivatives of analytic function, Taylor and Maclaurin series, Laurent's series, Poles and Residues, Evaluation of residues, Cauchy's residue theorem.

Text books

1. Jay L. Devore, Probability and Statistics for Engineering and the Sciences, 8th edition, Cengage, 2012.
2. Erwin Kreyszig, Advanced Engineering Mathematics, 10thEdition, John Wiley & Sons, 2016.

References

1. Peter V. O'Neil, Advanced Engineering Mathematics, Cengage, 7th Edition, 2012
2. Hossein Pishro-Nik, Introduction to Probability, Statistics and Random Processes, Kappa Research, 2014
3. Sheldon M. Ross, Introduction to probability and statistics for engineers and scientists, 4th edition, Elsevier, 2009.
4. T. Veera Rajan, Probability, Statistics and Random processes, Tata McGraw-Hill, 2008
5. Prof. Pranav Haridas, Complex Analysis, Kerala School of Mathematics, [NPTEL], https://nptel.ac.in/courses/111106141 (Relevant sections).

COURSE CONTENTS AND LECTURE SCHEDULE		
No.		No. of Hours
MODULE 1 [9 hours]		
1.1	Discrete random variables and their probability distributions	1
1.2	Discrete random variables and their probability distributions (Continued)	1
1.3	Expectation, mean and variance	1
1.4	Binomial distribution-mean and variance	1
1.5	Problems on Binomial distribution	1
1.6	Problems on Binomial distribution (continued)	1
1.7	Poisson distribution- Poisson approximation to binomial	1
1.8	Poisson distribution- mean and variance	1
1.9	Problems on Poisson distribution	1
MODULE II [9 hours]		
2.1	Continuous random variables and their probability distributions	1
2.2	Continuous random variables and their probability distributions(continued)	1
2.3	Expectation, mean and variance	1
2.4	Expectation, mean and variance(continued)	1
2.5	Uniform distribution – derivation of mean and variance	1
2.6	Problems on Uniform distribution	1
2.7	Normal distribution	1
2.8	Problems on Normal distribution	1
2.9	Problems on Normal distribution (continued)	1
MODULE III [9 hours]		
3.1	Population and samples, Sampling distribution of the mean and proportion (for large samples only)	1
3.2	Confidence interval for single mean	1
3.3	Confidence interval for single proportion	1
3.4	Test of Hypotheses: Large sample test for single mean	1
3.5	Large sample test for single proportion	1

3.6	Large sample test for equality of means	1
3.7	Small sample tests for single mean of normal population	1
3.8	Small sample t-tests for equality of means	1
3.9	Small sample t-tests for equality of means (continued)	1
MODULE IV [9 hours]		
4.1	Circles and disks, half planes, Complex functions	1
4.2	Limit and continuity of complex functions	1
4.3	Derivatives of complex functions	1
4.4	Analytic functions	1
4.5	Cauchy-Riemann equations	1
4.6	Cauchy-Riemann equations(continued)	1
4.7	Harmonic functions	1
4.8	Finding harmonic conjugate	1
4.9	Finding harmonic conjugate(continued)	1
MODULE V [9 hours]		
5.1	Cauchy’s integral theorem (without proof) on simply connected domain	1
5.2	Cauchy’s Integral formula (without proof)	1
5.3	Cauchy’s Integral formula for derivatives of analytic functions	1
5.4	Taylor’s series and Maclaurin series	1
5.5	Laurent series	1
5.6	Poles and Residues	1
5.7	Evaluation of residues	1
5.8	Evaluation of residues (continued)	1
5.9	Cauchy's residue theorem	1

CO Assessment Sample Questions	
1	1. A certain hospital usually admits 50 patients per day. On the average 3 patients in 100 require special facilities found in special rooms. On the morning of a certain day it is found that there are three such rooms available. Assuming that 50 patients will be admitted find the probability that more than 3 patients will require such special rooms. 2. Using CAS, determine the probability of rolling a sum of 7 or 11 when rolling two fair six-sided dice? Calculate the mean and variance of the probability distribution, generate random samples, and visualize the probability mass function.
	3. Team Work: Determine the probability of obtaining at least two heads when tossing a fair coin three times. Once the team has solved this problem, explore variations such as the probability of obtaining at least two heads when tossing the coin four times, or when using a biased coin with a 70% chance of heads and a 30% chance of tails. Explore these variations as a team and discuss the changes in probabilities.
2	1. A manufacturer knows from experience that the resistance of resistors he produces is normal with mean $\mu = 150\Omega$ and standard deviation $\sigma = 5\Omega$. What percentage of the resistors will have resistance between 148 Ω and 152 Ω? Between 140 Ω and 160 Ω? 2. A spinner selects a number X randomly from the interval $[0, 2\pi)$. The probability of selecting any number between 0 and x is proportional to the length of the interval $[0, x]$. Find the density function of X. What is the probability that the spinner selects a number between 2 and 3? Verify the answer using CAS. 3. Team Work: Calculate the probability that a normally distributed random variable with a mean of 75 and a standard deviation of 10 falls between 70 and 80? Additionally, generate random samples from this distribution and visualize the probability density function using CAS.

3	1. A manufacturer of nickel-hydrogen batteries randomly selects 100 nickel plates for test cells, cycles them a specified number of times, and determines that 14 of the plates have blistered. Does this provide compelling evidence for concluding that more than 10% of all plates blister under such circumstances? State and test the approximate hypothesis using a significance level of 0.05. 2. The mean produce of a sample of 100 fields is 200 lbs per acre with standard deviation of 10 lbs. Another sample of 150 fields gives the mean of 220 lbs with a standard deviation 12 lbs. Can the two samples be considered to have been take from the same population whose standard deviation is 11 lbs? Use 5% level of significance. Solve the problem using CAS and verify your answer. 3. Team Work: Using CAS, perform a hypothesis test to determine if there is a significant difference in the mean blood pressure between a control group and a treatment group. The datasets 'group1' and 'group2' represent the blood pressure measurements of the respective groups. Assume that the data follows a normal distribution and use a significance level of 0.05. Write CAS code to conduct the hypothesis test, calculate the test statistic, p-value, and provide a conclusion regarding the null hypothesis. Collaborate with your team members, execute the code, and interpret the results. Present your findings, discussing the hypothesis testing procedure and any notable observations made during the activity.

4	1. You are analyzing the flow of fluid in a river, and you want to understand the behavior of the velocity field. The velocity of the fluid is described by a complex function, where the real part represents the horizontal component and the imaginary part represents the vertical component. Apply the Cauchy-Riemann equations to determine the conditions under which the fluid flow is both irrotational (zero curl) and incompressible (zero divergence). 2. You are analyzing the flow of heat in a two-dimensional object, and the temperature distribution within the object is described by a harmonic function. For a particular case, let's consider a rectangular metal plate where the temperature distribution is given by $(x, y) = sin(x)cos(y)$, where (x, y) represents the spatial coordinates. Find the harmonic conjugate of the temperature function (x, y) and determine the streamlines of heat flow based on the harmonic conjugate. Verify the answer using CAS 3. Team Work: What are the critical points and equivalent resistances of a resistor with a nonlinear resistance described by the equation $R = a\|z\|^2 + b\|z\| + c$, where 'a', 'b', and 'c' are constants and 'z' is a complex variable representing the voltage across the resistor? Use complex differentiation to analyze the behavior of the resistor and find the critical points by differentiating the resistance equation with respect to 'z' and setting it equal to zero. Finally, substitute the critical points back into the resistance equation to determine the corresponding equivalent resistances.
5	1. In the study of a particle's motion along a curve, you aim to approximate the position function $x(t) = t^3 - 2t^2 + 3t - 1$ using a Taylor series expansion. Determine the Taylor series expansion of x(t) around t = 2 and use it to approximate the position of the particle at t = 2.2 up to the second-degree term. 2. The Maclaurin series $\frac{z}{e^z - 1} = 1 + B_1 z + \frac{B_2}{2!} z^2 + \frac{B_3}{3!} z^3 + \dots$ defines the Bernoulli numbers B_n. Using undetermined coefficients, show that $B = \frac{-1}{\ }$, $B = \frac{1}{\ }$, $B = 0$, $B = -\frac{1}{\ }$, $B = 0$, $B = \frac{1}{\ }$. Write a

	program 1 2 2 6 3 4 30 5 6 42 for computing B_n using CAS. Team Work: Research and find real-world applications of complex integration using the Cauchy Residue Theorem. Present your findings in a concise report or presentation, highlighting the applications and explaining how the theorem is used in each case.

24EST302	OVERVIEW OF CHEMICAL INDUSTRIES	L	T	P	J	S	C	Year of Introduction
		2	0	0	0	2	2	2024

Preamble: The aim of this course is to familiarize the budding chemical engineers to chemical industry operations. The subject reveals knowledge about operations of industries such as raw materials and products, unit operations and processes, engineering problems related to operations and marketing strategies currently followed in chemical industries, etc.
Students will get exposure through industrial visits to any of the industries like petroleum refinery, petrochemicals, fertilizers, natural products, polymer and Chlor-Alkali industries.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Identify unit operations and processes in industrial operations.
CO2	Select the raw materials for industrial products.
CO3	Sketch and explain the process flow diagram for the manufacture of industrial products.
CO4	Identify the major engineering problems in process industries
CO5	List the major content and prepare a detailed industrial visit report.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	3									2		1
CO 2	3									2		1
CO 3	3									2		1
CO 4	3									2		1
CO 5	3									2		1

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	
Understand	✔	✔	✔	
Apply	✔	✔	✔	
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
2-0-0-0	5	35	30	30	100

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	100	0	0

SYLLABUS

MODULE I: Introduction to chemical industries

Classification of chemical industries, Inorganic chemical industries: Manufacture of sulfuric acid, phosphoric acid, Chlor-Alkali industry-Chlorine and NaOH.

MODULE II: Fertilizer Industries

Fertilizers: Production of Ammonia, Urea, Single Super Phosphate (SSP) and Triple Super Phosphate (TSP).

MODULE III: Natural products industries

Natural products industries: Manufacture of -Pulp and Paper, Sugar, Oil, and Fats.

MODULE IV: Petroleum refining and petrochemicals

Petroleum refinery operations: pretreatment, atmospheric distillation unit, Petrochemicals: Manufacture of acetylene, butane, phenol.

MODULE V: Polymerization industries

Polymerization industries: Polyethylene, Polypropylene, PVC, and polyester synthetic fibers (nylon - 6, nylon - 6,6).

Pharmaceutical industries: History and Growth, Methods of production-Raw materials-Antibiotics-Synthetic drugs-vitamins-Synthetic hormones-Vaccines & Sera.

*Students must undergo an industrial visit at any of the following industries and prepare a report with the importance, raw materials, overall process, and products. The types of industries may include chemical industries, chlor-alkali industries, fertilizers, natural products, petroleum, petrochemicals, polymerization industries and pharmaceutical industries

Textbooks

1. C.E. Dryden, Outlines of Chemical Technology, Edited and revised by M. Gopala Rao and Marshall Sitting, 2nd Ed., Affiliated East-West Press, 1973.
2. G.T. Austin, R.N. Shreve, Chemical Process Industries, 5th Ed., McGraw Hill,

1984.

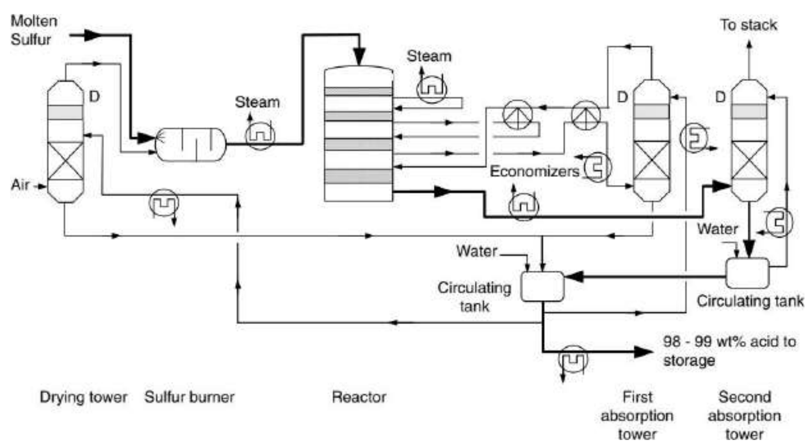
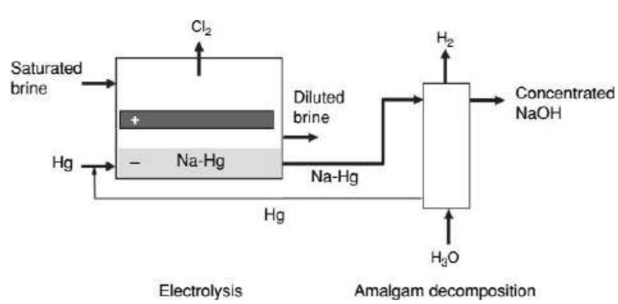
Reference books

1. J.A. Moulijn, M. Makkee, A.V Diepen, Chemical Process Technology, 2nd Ed., Wiley, 2015.
2. P.H. Groggins, Unit Processes in Organic Synthesis, 5th Ed., McGraw Hill, 2001.
3. D.F. Kirk-Othmer,Encyclopedia of Chemical Technology, 5th Ed., Wiley Interscience, 2004.
4. J.H. Gary, G.E. Handwerk, Petroleum Refining: Technology and Economics, 1st Ed., Marcel Dekker, 2001.
5. S. Sarkar, Fuels and Combustion, 3rd Ed., Universities Press, 2009.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE 1 (6 hours)		
1.1	Manufacturing of sulfuric acid.	1
1.2	Manufacturing of sulfuric acid.	1
1.3	Manufacturing of phosphoric acid.	1
1.4	Manufacturing of phosphoric acid.	1
1.5	Chlor-Alkali industry process: Chlorine and NaOH.	1
1.6	Chlor-Alkali industry process: Chlorine and NaOH.	1
MODULE II (4 hours)		
2.1	Production of Ammonia.	1
2.2	Manufacturing of Urea.	1
2.3	Manufacturing of Single Super Phosphate (SSP).	1
2.4	Manufacturing of Triple Super Phosphate (TSP).	1
MODULE III (3 hours)		
3.1	Manufacturing of Pulp and Paper.	1
3.2	Manufacturing of Sugar.	1
3.3	Processing of Oil and Fats.	1
MODULE IV (5 hours)		
4.1	Petroleum refinery operations: Crude oil types, properties, pretreatment.	1
4.2	Petroleum refinery operations: Atmospheric distillation unit.	1

4.3	Petrochemicals: Manufacture of acetylene.	1
4.4	Manufacture of butane.	1
4.5	Manufacture of phenol.	1
	MODULE V (4 hours)	
5.1	Manufacturing of polyethylene, Polypropylene.	1
5.2	Manufacturing of PVC, Polyester.	1
5.3	Manufacturing of synthetic fibers (nylon - 6, nylon - 6,6).	1
5.4	Pharmaceutical industries: History and Growth, Methods of production-Raw materials.	1
5.5	Antibiotics-Synthetic drugs-vitamins.	1
5.6	Synthetic hormones-Vaccines & Sera.	1

<table>
<tr><td colspan="2">CO Assessment Sample Questions</td></tr>
<tr><td>CO1</td><td>Describe the process in the following diagram with the raw materials,
process utilities and the final product with its assay.</td></tr>
<tr><td></td><td>
</td></tr>
<tr><td>CO1</td><td>Identify the process and products from the following diagram.
Explain the process in detail.

</td></tr>
<tr><td>CO2</td><td>Describe the major engineering problems that arise in the chlorine
manufacturing process.</td></tr>
<tr><td>CO3</td><td>List and explain the petrochemical products and its applications.</td></tr>
<tr><td>CO4</td><td>List the types of raw materials and explain the manufacturing of paper.</td></tr>
</table>

CO5	Prepare a detailed report on raw materials, products, process layout, process description and utilities of industrial visit carried out.

24CHJ303	SUSTAINABLE DEVELOPMENT AND POLLUTION CONTROL	L	T	P	J	S	C	Year of Introduction
		2	0	2	2	5	5	2024

Preamble: Objective of this course is to inculcate in students an awareness of environmental issues and the global initiatives towards attaining sustainability. The student should realize the potential of technology in bringing in sustainable practices. This course familiarizes students with the concepts of life cycle analysis, its applications, environmental pollution and solutions for sustainability.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Explain the relevance and the concept of sustainability and the global initiatives in this direction.
CO2	Explain the different types of environmental pollution problems and their sustainable solutions.
CO3	Describe the goal and scope of life cycle assessment.
CO4	Apply LCA software for various products.
CO5	Demonstrate the broad perspective of sustainable practices by utilizing engineering knowledge and principles.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3					2	3					2
CO2	3	2		3		2	3	2	2	2		2
CO3	3					2	3					2
CO4	3			3	2	2	3	2	2	2		2
CO5	3	2				2	3					2

Assessment Pattern for Theory component

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test 1	Test 2	Other tools	
Remember		✔	✔	✔
Understand		✔	✔	✔
Apply		✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Assessment Pattern for Lab component		
Bloom's Category	**Continuous Assessment Tools**	
	Class work	**Test1**
Remember		
Understand	✔	✔
Apply	✔	✔
Analyse	✔	✔
Evaluate		
Create		

Assessment Pattern for Project component

Bloom's Category	**Continuous Assessment Tools**		
	Evaluation 1	**Evaluation 2**	**Report**
Remember			
Understand	✔	✔	
Apply	✔	✔	
Analyse	✔	✔	
Evaluate		✔	
Create		✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	**Attendance**	**Theory [L- T]**		**Practical [P]**	**Project [J]**			**Total Marks**
		Assignment	Test-2	Class work	Evaluation 1	Evaluation 2	Report	
2-0-2-2	5	10	10	15	5	10	5	60

Total Marks distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	60	40	2.5 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks

PATTERN 2		2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x 8 = 40 marks) Time: 2.5 hours	40
	Total Marks: 0	Total Marks: [5x8 = 40 marks]	

SYLLABUS
MODULE I: Introduction to sustainability
Sustainability: Introduction, reasons for unsustainability, concept, evolution of the concept; Social, environmental and economic sustainability concepts; Sustainable development, Nexus between Technology and Sustainable development; Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs), Clean Development Mechanism (CDM).
MODULE II : Introduction to environmental pollution
Environmental Pollution: Air Pollution and its effects, Estimation of air quality index, Water pollution and its sources, Soil pollution, Zero waste concept and 3 R concepts in solid waste management; Carbon credits, carbon trading and carbon foot print, legal provisions for environmental protection.
MODULE III : Introduction to Life Cycle Analysis
Life Cycle Analysis (LCA) – Introduction, ISO standards, LCA framework, Goal; Scope – Functional unit, Product Systems, System Boundary; Inventory Analysis; Impact Assessment; Interpretation.
MODULE IV : Applications of LCA
Sustainability issues in major industrial sectors including process industries, agriculture and food, automobiles, personal care products and energy. Application of LCA software in these sectors.
MODULE V : Solutions for sustainability
Designing sustainable processes and products, ecosystem ecology, industrial symbiosis and the circular economy, ecosystems in engineering, economic policies, societal development.

Text books

1. Allen, D. T. and Shonnard, D. R., Sustainability Engineering: Concepts, Design and Case Studies, Prentice Hall.
2. Bakshi, B.R., Sustainable Engineering:Principles and Practice, Cambridge University Press.

Reference books

1. Bradley. A.S; Adebayo,A.O., Maria, P. Engineering applications in sustainable design and development, Cengage learning.
2. Ni bin Chang, Systems Analysis for Sustainable Engineering: Theory and Applications, McGraw-Hill Professional.
3. Purohit, S. S., Green Technology – An approach for sustainable environment, Agrobios Publication.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours (24)
	MODULE 1 (6 hours)	
1.1	Sustainability: Introduction, reasons for unsustainability.	1
1.2	Concept, evolution of the concept, Social sustainability concepts.	1
1.3	Environmental and economic sustainability concepts.	1
1.4	Sustainable development, Nexus between Technology and Sustainable development.	1
1.5	Millennium Development Goals (MDGs), Sustainable Development Goals (SDGs), Clean Development Mechanism (CDM).	1
1.6	Clean Development Mechanism (CDM).	1
	MODULE II (5 hours)	
2.1	Environmental Pollution: Air Pollution and its effects.	1
2.2	Water pollution and its sources.	1
2.3	Soil pollution.	1
2.4	Zero waste concept and 3 R concepts in solid waste management, Carbon credits.	1
2.5	Carbon trading and carbon foot print, Legal provisions for environmental protection.	1
	MODULE III (5 hours)	
3.1	Life Cycle Analysis (LCA) – Introduction.	1
3.2	ISO standards, LCA framework.	1
3.3	Goal of LCA, Scope – Functional unit, Product Systems, System	1

	Boundary.	
3.4	Inventory Analysis.	1
3.5	Impact Assessment; Interpretation.	1
MODULE IV (4 hours)		
4.1	Sustainability issues in major industrial sectors including agriculture and food, automobiles, personal care products and energy.	1
4.2	Application of LCA software in the agricultural industry.	1
4.3	Application of LCA software in the food industry, automobile industry.	1
4.4	Application of LCA software in personal care products, energy sector.	1
MODULE V (4 hours)		
5.1	Designing sustainable processes and products, ecosystem ecology.	1
5.2	Symbiosis and the circular economy.	1
5.3	Ecosystems in engineering, economic policies.	1
5.4	Societal development.	1

LAB COMPONENT

Including laboratory experiments in a course is an excellent way to enhance the understanding of various concepts in the syllabus. It provides students with hands-on experience and practical application of the theoretical knowledge they acquire in the classroom. It also fosters critical thinking, problem-solving, and practical skills that are valuable in their academic and professional pursuits. Here are some key points to consider when incorporating laboratory experiments into a course:

Alignment with Course Objectives: Ensure that the laboratory experiments align with the course objectives and learning outcomes. The experiments should reinforce and complement the concepts taught in the classroom.

Relevance: Select experiments that are relevant to the course material and provide real-world examples of the concepts being discussed. This helps students see the practical applications of what they are learning.

Safety: Safety is paramount in a laboratory setting. Make sure that all experiments are conducted in a safe environment, and students are aware of the safety protocols and precautions.

Equipment and Materials: Ensure that the necessary equipment and materials are available and in good working condition. Students should have access to the tools and resources needed to conduct the experiments effectively.

Clear Instructions: Provide clear and detailed instructions for each experiment. This should include the purpose of the experiment, the procedures to be followed, data collection methods, and any specific requirements.

Data Analysis and Interpretation: Include a component for data analysis and interpretation in the laboratory reports. This encourages critical thinking and helps students draw meaningful conclusions from their experiments.

Variety: Offer a variety of experiments that cover different aspects of the course material. This can include quantitative experiments, qualitative observations, and even open-ended, exploratory experiments.

Feedback and Assessment: Develop a system for assessing and providing feedback on students laboratory reports and performance. This assessment should contribute to their overall course grade.

Integration with Theory: Encourage students to connect the results of their experiments with the theoretical concepts discussed in the classroom. This reinforces their understanding and helps bridge the gap between theory and practice.

Practical Skills: Besides reinforcing theoretical knowledge, laboratory experiments should also help students develop practical skills, such as experimental design, data collection, and analysis.

Reflection: Encourage students to reflect on their experiences during the experiments. This can be done through post-lab discussions or written reflections, allowing students to think critically about what they learned.

Flexibility: Be open to adapting the laboratory component as needed. Sometimes, students may discover unexpected results or encounter challenges. This flexibility can turn such situations into valuable learning experiences.

Resources and Support: Provide access to resources, including lab manuals, research papers, and additional readings, to help students delve deeper into the concepts explored in the experiments.

LESSON PLAN FOR LAB COMPONENT

No.	Topic	No. of Hours (24)	Experiment
1	Water Pollution	2	Water analysis – hardness, chloride content.
2	Water Pollution	2	Estimating the COD of the given water sample.
3	Water Pollution	2	Estimating the DO and BOD of the given water sample.
4	Water Pollution	2	Estimating the total solids and dissolved solids content in the given water sample.
5	Water Pollution	2	Analysis of oil and grease in the given wastewater sample.
6	Water Pollution	2	Estimation of Iodine value/acid value of the given sample of oil.
7	Water Pollution	2	Estimation of available chlorine in bleaching

			powder.
8	LCA	2	LCA of various products.
9	Solid waste management	2	To find the moisture content and ash content of the given
			solid waste.
10	Noise pollution	2	To find the level of noise pollution in a given area.
11	Solid waste management	2	Proximate analysis.
12	Characterization	2	Study of equipments – Redwood viscometer, Junker's gas calorimeter, Flash and fire point apparatus. Study of bomb calorimeter etc.

COURSE PROJECT

Incorporating a project component in a course complements theoretical learning and laboratory experiments by providing students with the opportunity to synthesize, apply, and deepen their understanding of course concepts. It also encourages critical thinking, problem-solving, and creativity, which are valuable skills for students academic and professional growth. Here are some key points to consider when including a project component in a course to cover the concepts from the syllabus:

Alignment with Course Objectives: Ensure that the project aligns with the course objectives and learning outcomes. The project should provide an opportunity for students to apply the theoretical knowledge they have gained.

Relevance: Select project topics that are directly related to the course material. The project should enable students to explore and apply the concepts covered in the classroom and laboratory sessions.

Project Types: Consider various project types, such as group projects, case studies, or practical applications. The choice of project type should depend on the course goals and the specific concepts being covered.

Clear Guidelines: Provide clear project guidelines and expectations. Include information on project deliverables, deadlines, and assessment criteria to ensure that students understand what is expected of them.

Student Choice: If possible, allow students to choose project topics that align with their interests or career goals. This can increase motivation and engagement.

Resources and Support: Ensure that students have access to the necessary resources, including literature, software, equipment, or guidance from instructors or mentors.

Interdisciplinary Approach: Encourage interdisciplinary projects that draw on concepts from multiple areas of the syllabus. This can promote a holistic understanding of the subject matter.

Peer Collaboration: Encourage collaboration among students for group projects. Teamwork can foster problem-solving skills and diverse perspectives.

Reflection and Presentation: Require students to reflect on their project experiences and present their findings to the class. This promotes critical thinking and communication skills.

Assessment Criteria: Clearly define how the project component will be graded. Assess not only the final product but also the process, research, problem-solving, and communication skills.

Feedback and Revision: Provide feedback on project proposals and guide students in the right direction. Allow them to revise and improve their work based on feedback.

Integration with Theory and Lab: Emphasize the connection between the project and the theoretical and laboratory components of the course. Encourage students to apply what they have learned in these sessions to their projects.

Real-World Applications: Whenever possible, choose projects that have real-world applications. This can help students see the practical relevance of their coursework.

Sample project topics for students to work on:

1	Using LCA, choose between plastic bag and paper bag.
2	Using LCA, choose between soyabean oil and groundnut oil.
3	Analysis of drinking water sample in your house and check whether it is meeting the drinking water standards.

<u>Note</u>:-Projects need not be restricted to the above topics. Students are encouraged to choose any application problems, in the course domain, which they desire to work on.

LESSON PLAN FOR PROJECT COMPONENT

The concepts in the syllabus that can be covered through the project shall be included in the project component part to ensure comprehensive coverage of the course through theory, lab and project sessions. Total No. of Class Hours: 24 12 Hours of self-study hours also should be utilized for the development of the complete project.		
No.	Topic	No. of Class Hours [24]
1	Preliminary Design of the Project.	4
2	Zeroth presentation (4th week).	2
3	Project work - First Phase.	4
4	Interim Presentation (7th and 8th weeks).	4
5	Project work - Final Phase & Report writing (discussions in class during project hours).	6
6	Final Evaluation and Presentation (11th and 12th weeks).	4

CO Assessment Sample Questions	
1	Explain with an example a technology that has contributed positively to sustainable development.
2	Explain any one environmental pollution problem and suggest a sustainable solution.
3	Explain the importance of conducting life cycle assessment of a product.
4	How can LCA support the circular economy?
5	Suggest suitable measures to make the conveyance facilities used by your institution sustainable.

24CHP304	CHEMISTRY FOR PROCESS ENGINEERS	L	T	P	J	S	C	Year of Introduction
		2	1	2	0	4	4	2024

Preamble: Important topics from physical chemistry which are very much relevant to process engineering students are introduced in the course. The course covers a variety of topics such as solid state, colligative properties of solutions, colloids, surface chemistry, etc. In addition to these a module discussing the theory and instrumental techniques that encompass electroanalytical measurements is also included. The students are expected to attain the skill to solve various physical chemistry problems.

Prerequisite: Basic knowledge in Engineering Chemistry.

Course Outcomes: After the completion of the course the student will be able to

CO1	Describe specific crystal structures by applying basic crystallographic concepts and XRD patterns of materials [Understand level]
CO2	Describe the effects of solute concentration on the osmotic pressure, vapor pressure, boiling point and freezing point of a solution [Understand level]
CO3	Describe the synthesis, purification and application of colloids [Understand level]
CO4	Interpret different adsorption isotherms and information on a material's surface composition and topography from various microscopic images [Apply level]
CO5	Identify the suitable electrochemical analytical technique for the characterization of materials and interpret the data [Apply level]
CO6	Quantify the analyte using electrochemical analytical techniques, investigate the kinetics of a reaction, describe the mutual solubilities of liquids and apply the idea to find out the unknown concentration of a solute [Apply level]

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	3	1										1
CO 2	3	1										1
CO 3	3	1										1
CO 4	3	1			1							1
CO 5	3	1			1		1					1
CO 6	2	1			1			1	1	1		1

Assessment Pattern for Theory component

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Assessment Pattern for Lab component

Bloom's Category	Continuous Assessment Tools	
	Class work	Test1
Remember		
Understand	✔	✔
Apply	✔	✔
Analyse	✔	✔
Evaluate	✔	
Create	✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Practical [P]		Total Marks
		Assignment	Test-1	Test-2	Class work	Lab Exam	
2-1-2-0	5	10	10	10	15	10	60

Total Marks distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	60	40	2.5 h

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks

PATTERN 2		2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x 8 = 40 marks) Time: 2.5 hours	40
	Total Marks: 0	Total Marks: [5x8 = 40 marks]	

SYLLABUS
MODULE I: Solid state
Types of solids, Difference between crystalline and amorphous solids, Elements of symmetry, space lattice and unit cell, Bravais lattices, seven crystal systems, law of rational indices, Miller Indices, X-ray diffraction, Derivation of Bragg's equation, XRD patterns of a cubic system, Powder diffraction, Neutron diffraction, Types of crystals-introductions to molecular, covalent, metallic and ionic crystals
MODULE II: Colligative Properties of Dilute Solutions
Dilute solutions, Colligative properties, lowering of vapour pressure-Raoult's law, determination of molecular mass from vapour pressure lowering, numerical, Elevation in boiling point- determination of molecular mass from elevation in boiling point, numerical, Depression in freezing point-determination of molecular weight from depression in freezing point, numerical Osmotic pressure, van't Hoff's equation for osmotic pressure, determination of molar mass, Abnormal molar masses of solutes and van't Hoff factor.
MODULE III: Colloids

Classification of colloids, Preparation of colloids - dispersion and condensation methods, Purification of colloids – dialysis and ultrafiltration, Properties of colloids - kinetic, optical and electrical properties, Origin of charge on colloids, Electrical double layer, Zeta potential- factors affecting, determination of zeta potential, Electrokinetic properties-electrophoresis, electro-osmosis, Determination of size of colloids, Protective colloids, Gold number, stability of colloids, Application of colloids – Cottrell precipitator, purification of water and delta formation
MODULE IV: Surface Chemistry
Adsorption- Types, Adsorption Isotherms – Langmuir, Freundlich, and BET equations (no derivation for BET). Determination of surface area using BET equation. Gibbs adsorption isotherm –derivation, Gibbs surface excess. Surface Characterization by Microscopy- Principle, instrumentation and applications of Scanning electron microscope (SEM), scanning tunneling microscope (STM) and atomic force microscope (AFM).
MODULE V: Electroanalytical techniques
Conductometry- principle, determination of equivalence points for acid–base titrations, Potentiometry – principle, determination of equivalence point for acid–base titration, Polarography- principle, residual current, migration current, diffusion current (Ilkovic equation) and limiting current, half wave potential, applications, Anodic stripping voltammetry- principle, working, applications, Amperometry-principle, , Electrochemical sensors (Biosensors for glucose, ethanol
and urea, gas sensors for Oxygen and CO_2)
Text books 1. B. R. Puri, L.R. Sharma, M.S. Pathania, Principles of Physical Chemistry, Vishal Publishing Co., 2013. 2. R. L. Madan and G. D. Tuli Physical Chemistry, published by S. Chand Publishing, Edition 2016 3. A. Bahl, B. S Bhal and G D Tuli, Essentials of Physical Chemistry, S. Chand Publishing, Edition 2010

Reference books

1. F. W. Fifield, Principles and Practice of Analytical Chemistry, Wiley-Blackwell; 5th edition, 2000
2. J. B. Yadav, Advanced Practical Physical Chemistry, Goel Publications, 2017 Edition
3. Gary D. Christian, Analytical Chemistry, 6th Edition Wiley; Sixth edition (2007)
4. D. N. Bajpai, O. P. Pandey and S. Giri, Practical Chemistry, S Chand & Co Ltd, 2015 Edn.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE 1 (7 hours)		
1.1	Types of solids, Difference between crystalline and amorphous solids, Elements of symmetry	1
1.2	space lattice and unit cell, Bravais lattices, seven crystal systems, law of rational indices, Miller Indices	1
1.3	X-ray diffraction, Derivation of Bragg's equation	1
1.4	XRD patterns of a cubic system	1
1.5	Powder diffraction	1
1.6	Neutron diffraction	1
1.7	Types of crystals-introductions to molecular, covalent, metallic and ionic crystals	1
MODULE II (8 hours)		
2.1	Dilute solutions, Colligative properties, lowering of vapour pressure-Raoult's law	1
2.2	Determination of molecular mass from vapour pressure lowering, numerical	1
2.3	Elevation in boiling point	1
2.4	determination of molecular mass from elevation in boiling point, numerical	1
2.5	Depression in freezing point	1
2.6	determination of molecular weight from depression in freezing point, numerical	1
2.7	Osmotic pressure, van't Hoff's equation for osmotic pressure, determination of molar mass	1
2.8	Abnormal molar masses of solutes and van't Hoff factor	1
MODULE III (7 hours)		

3.1	Classification of colloids, Preparation of colloids - dispersion and condensation methods	1
3.2	Purification of colloids – dialysis and ultrafiltration, Properties of colloids - kinetic, optical and electrical properties	1
3.3	Origin of charge on colloids, Electrical double layer	1
3.4	Zeta potential- factors affecting, determination of zeta potential,	1
3.5	Electrokinetic properties-electrophoresis, electro-osmosis	1
3.6	Determination of size of colloids, Protective colloids, Gold number	1
3.7	stability of colloids, Application of colloids – Cottrell precipitator, purification of water and delta formation.	1
MODULE IV (7 hours)		
4.1	Adsorption- Types, Adsorption Isotherm – Langmuir	1
4.2	Adsorption Isotherm - Freundlich	1
4.3	BET equations (no derivation for BET). Determination of surface area using BET equation	1
4.4	Gibbs adsorption isotherm –derivation, Gibbs surface excess	1
4.5	Principle, instrumentation and applications of Scanning electron microscope (SEM)	1
4.6	Principle, instrumentation and applications of scanning tunneling electron microscope (STM)	1
4.7	Principle, instrumentation and applications of atomic force microscope (AFM).	1
MODULE V (7 hours)		
5.1	Conductometry- principle, determination of equivalence points for acid–base titrations	1
5.2	Potentiometry – principle, determination of equivalence point for acid–base titration	1
5.3	Polarography- principle, residual current, migration current, diffusion current (Ilkovic equation)	1
5.4	limiting current, half wave potential, applications, Anodic stripping voltammetry-principle, working, applications	1
5.5	Amperometry-principle	1
5.6	Electrochemical sensors-Biosensors for glucose, ethanol and urea	1
5.7	Gas sensors for Oxygen and CO_2	1

LESSON PLAN FOR LAB COMPONENT (Any 6 experiments to be conducted)

No.	Topic	No. of Hours	Experiment
1	Electroanalytical methods	4	Experiment 1: Determine the end point of titration between CH_3COOH and NaOH by conductometric titration Experiment 2: Determine the composition of mixture of acetic acid and hydrochloric acid by conductometric titration Experiment 3: Potentiometric acid-base titration Experiment 4: Titration of Zn(II) by $K_4[Fe(CN)_6]$ potentiometrically
2	Phase rule	2	Experiment 5: Mutual solubility curve of phenol and water (or trimethylamine and water) and determination of CST Experiment 6: Determine the concentration of aqueous KCl solution by studying the mutual solubility of phenol and water
3	Partition coefficient	2	Experiment 7: Partition coefficient of Succinic acid between water and ether. Experiment 8: Study the distribution of benzoic acid between benzene and water and show that benzoic acid dimerizes in benzene
4	Colligative properties	3	Experiment 9: Determine the molecular weight of a non-volatile substance (acetanilide/urea/naphthalene/anthracene/thiourea etc..) using Rast method- camphor as solvent Experiment 10: Determination of molal transition point depression constant Experiment 11: Determination of transition temperature of salt hydrate
5	Adsorption	2	Experiment 12: Investigate the adsorption of oxalic acid by charcoal and examine the validity of Freundlich and Langmuir isotherms Experiment 13: Determination of unknown concentration of oxalic acid from adsorption experiment

6	Kinetics	2	Experiment 14: Study the kinetics of the reaction between potassium persulphate and potassium iodide Experiment 15: Study the kinetics of acid hydrolysis of methyl acetate

CO Assessment Sample Questions	
1	a) Compare the X-ray powder diffraction patterns of NaCl and KCl and show that unit cell length of KCl is larger than that of NaCl. b) Describe how XRD can be used for phase identification.
2	a) Explain why 0.60 grams of acetic acid dissolve in 200 grams of benzene to form a solution that lowers the freezing point of benzene to 5.40^{o}C. b) Determine the molecular weight of acetic acid if a solution that contains 30.0 grams of acetic acid per kilogram of water freezes at -0.93^{o}C. Do these results agree with the assumption that acetic acid has the formula CH_3COOH?
3	a) Describe a few of the food chemistry concepts linked to colloids, such as how to prepare butter, stabilize milk, and cook eggs in different ways. b) Describe the role of colloids in wastewater treatment.
4	c) Explain how the adsorption of a molecule on a surface can be studied using scanning electron microscope. d) Explain with examples from literature, how the scanning tunneling microscope (STM) and the atomic force microscope (AFM) are capable of resolving surface detail down to the atomic level.
5	a) If your sample was known to contain metal ions that cannot be measured by ASV, what other techniques would you suggest trying? b) Identify an electroanalytical technique to determine the concentration of Pb^{2+} in a water sample. Justify your answer
6	a) Conduct volumetric, conductometric and potentiometric acid-base titrations and compare the results.

24CHT305	MATERIAL & ENERGY BALANCE COMPUTATIONS	L	T	P	J	S	C	Year of Introduction
		2	1	0	0	2	3	2024

Preamble: This course aims to establish fundamental principles of Chemical Engineering in a simple and up-front manner and provide a broad background for applying these principles to industrial and theoretical problems. This course introduces students to basic concepts of composition calculations practiced in chemical processes, equations of states, material and energy balances, which are fundamental and core areas of the Chemical Engineering course.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to:

CO1	Determine the composition of solids, liquids, and solutions using weight percentage, mole percentage, molarity, molality, normality, and parts per million (PPM).
CO2	Apply the principles of gas laws, including the Ideal Gas Law, Dalton's Law, and Amagat's Law in calculations involving the composition, average molecular weight, and density of gaseous mixtures.
CO3	Use equations of state, such as the Van der Waals Equation, to describe the behavior of gases under different conditions.
CO4	Solve basic material balance equations for the unit operations and unit processes employed in process industries.
CO5	Solve energy balance equations for various physical and chemical processes.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3										2
CO2	3	3										2
CO3	3	3										2
CO4	3	3	2									2
CO5	3	3	2									2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	**Attendance**	**Theory [L- T]**			**Total Marks**
		Assignment	**Test-1**	**Test-2**	
2-1-0-0	05	15	10	10	40

Total Mark distribution

Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 Hours

End Semester Examination [ESE]: Pattern

PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Solids, Gases, Vapours, and Liquids

Composition of Solids – weight percentage and mole percentage.
Composition of liquids and solutions – weight percentage, mole percentage, molarity, molality, normality, PPM.
Gaseous mixtures – composition, average molecular weight, and density.
Concept of critical property. Gas laws – Ideal gas law, Dalton's law, and Amagat's law.
Equations of state – Van der Waals Equation. Vapour pressure - Clausius-Clapeyron equation. Ideal and non-ideal solutions - Raoult's law & Henry's law.

MODULE II: Material Balances for Unit Operations
Concept of material balance, open and closed systems, steady state and unsteady state, multiple component systems, selection of a basis, key component, problem-solving strategy. Conservation of mass, material balance for systems without chemical reactions – Mixing, Distillation, Evaporation, and Absorption. Recycle, purge, and bypass calculations.
MODULE III: Material Balances for Reactive Processes
Definition of terms: limiting reactant, excess reactant, percentage yield, conversion, and selectivity. Concept of stoichiometry and mole balances, Combustion of solids, liquids, and gaseous fuels. Calorific Value. Orsat Analysis. Proximate and Ultimate Analysis of Coal.
MODULE IV: Energy Balance on Nonreactive Processes
Elements of energy balance calculations – reference states, hypothetical process paths, and procedure for energy balance calculations. Changes in temperature – sensible heat and heat capacities, heat capacity formulas, estimation of heat capacities, energy balances on single phase systems. Phase change operations – latent heats, estimation and correlation of latent heats, energy balance on processes involving phase changes.
MODULE V: Energy Balance on Reactive systems
Heat of reaction – measurement, and calculation of heat of reaction – Hess's law. Formation reaction and heat of formation. Heat of combustion, and determination of temperatures for adiabatic and nonadiabatic reactions.
Textbooks 1. Himmelblau, D. M., Riggs, J. B. "Basic Principles and Calculations in Chemical Engineering", Eighth Ed., Pearson India Education Services, 2015. 2. Bhatt, B. I., Vora, S. M., "Stoichiometry", Fourth Edition, Tata McGraw Hill Publishing Company Ltd, 2004. 3. Narayanan K.V. and Lakshmikutty B., "Stoichiometry and Process Calculations", Prentice Hall of India, 2006.

Reference books

1. V. Venkataramani, N. Anantharaman, and K.M. Meera Sheriffa Begum., "Process Calculations", Second Edition, PHI Learning Private Limited, 2011.
2. Felder, R. M.; Rousseau, R. W., "Elementary Principles of Chemical Processes", Third Edition, John Wiley & Sons, 2000.
3. Hougen, O. A., Watson, K. M., Ragatz, R. A., "Chemical Process Principles, Part-I Material & Energy Balances", Second Edition, CBS Publishers & Distributors, 2004.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1 (9 Hours)	
1.1	Composition of Solids – weight percentage and mole percentage.	1
1.2	Composition of liquids and solutions – weight percentage, mole percentage, molarity, molality, normality, PPM.	1
1.3	Composition of liquids and solutions – weight percentage, mole percentage, molarity, molality, normality, PPM.	1
1.4	Gaseous mixtures – composition, average molecular weight, and density. Concept of critical property.	1
1.5	Gaseous mixtures – composition, average molecular weight, and density. Concept of critical property.	1
1.6	Gas laws – Ideal gas law, Dalton's law, and Amagat's law.	1
1.7	Equations of state – Van der Waals Equation.	1
1.8	Vapour pressure - Clausius-Clapeyron equation.	1
1.9	Ideal and non-ideal solutions - Raoult's law & Henry's law.	1
	MODULE II (8 Hours)	
2.1	Concept of material balance, open and closed systems, steady state and unsteady state	1
2.2	multiple component systems, selection of a basis, key component, problem-solving strategy	1

2.3	multiple component systems, selection of a basis, key component, problem-solving strategy	1
2.4	Conservation of mass, material balance for systems without chemical reactions – Mixing	1
2.5	material balance for systems without chemical reactions – Distillation, Evaporation	1
2.6	material balance for systems without chemical reactions – Absorption	1
2.7	Recycle, purge, and bypass calculations	1
2.8	Recycle, purge, and bypass calculations	1
MODULE III (7 Hours)		
3.1	Definition of terms: limiting reactant, excess reactant, percentage yield, conversion, and selectivity.	1
3.2	Definition of terms: limiting reactant, excess reactant, percentage yield, conversion, and selectivity.	1
3.3	Concept of stoichiometry and mole balances	1
3.4	Combustion of solids, liquids, and gaseous fuels, calorific value	1
3.5	Combustion of solids, liquids, and gaseous fuels, calorific value	1
3.6	Orsat Analysis.	1
3.7	Proximate and Ultimate Analysis of Coal.	1
MODULE IV (7 Hours)		
4.1	Elements of energy balance calculations – reference states, hypothetical process paths, and procedure for energy balance calculations.	1
4.2	Elements of energy balance calculations – reference states, hypothetical process paths, and procedure for energy balance calculations.	1
4.3	Changes in temperature – sensible heat and heat capacities, heat capacity formulas, estimation of heat capacities, energy balances on single phase systems.	1
4.4	Changes in temperature – sensible heat and heat capacities, heat capacity formulas, estimation of heat capacities, energy	1

	balances on single phase systems	
4.5	Phase change operations – latent heats, estimation and correlation of latent heats	1
4.6	Phase change operations – latent heats, estimation and correlation of latent heats	1
4.7	Energy balance on processes involving phase changes.	1
	MODULE V (5 Hours)	
5.1	Heat of reaction – measurement, and calculation of heat of reaction – Hess's law.	1
5.2	Heat of reaction – measurement, and calculation of heat of reaction – Hess's law.	1
5.3	Formation reaction and heat of formation	1
5.4	Heat of combustion, and determination of temperatures for adiabatic and nonadiabatic reactions.	1
5.5	Heat of combustion, and determination of temperatures for adiabatic and nonadiabatic reactions.	1

CO Assessment Sample Questions

1	The molecular formula of an organic compound is $C_{10}H_7Br$. Find the weight percentage of carbon, hydrogen and bromine in the solid.
2	Natural gas has the following composition by volume percent. CH4 – 83.5%; C2H6 – 12.5% and rest Nitrogen. Calculate: Composition in mole % Composition in Wt% Average molecular weight.
3	Calculate the pressure developed by one kmol of NH3 gas contained in a vessel of 0.6m3 capacity at a constant temperature of 473 K using Van der Waals equation. Given that a = 0.4233 Nm4/mol2 and b = 3.73 x 10-5 m3/mol.

4	1000 kg of mixed acid of composition 40% H2SO4, 45% HNO_3 and 15% H_2O is to be produced by strengthening waste acid of composition 30% H_2SO_4, 36% HNO_3 and 34% H_2O by weight. Concentrated sulphuric acid of strength 95% and concentrated nitric acid containing 80% acid are available for this purpose. Calculate in kilograms, the amount of spent acid and concentrated acid to be mixed together.
5	A fuel oil containing 88.2% Carbon and 11.8% Hydrogen (by weight) is burnt with 20% excess air. 95% of the carbon is burnt to carbon dioxide and the rest to carbon monoxide. All the hydrogen is converted to water. Determine the Orsat analysis of the flue gas.

24HUT310	LIFE SKILLS AND PROFESSIONAL ETHICS	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: The objective of this course is to enhance the employability and maximize the potential of the students by introducing them to the principles underlying personal and professional success. It equips them with the necessary skills to apply these principles effectively in their lives and careers. This course covers essential life skills for personal and professional success, introduces creative problem-solving techniques, fosters teamwork and leadership qualities, highlights the core values of professional ethics, and explains how individuals play a crucial role in technological development while maintaining personal and legal ethical standards.

Prerequisite: NIL

Course Outcomes: After the completion of the course the student will be able to

CO1	Describe different life skills required in personal and professional life (Understand Level)
CO2	Illustrate appropriate thinking and problem-solving techniques to solve new problems creatively (Apply Level)
CO3	Demonstrate the basics of teamwork and leadership qualities (Apply Level)
CO4	Identify the core values that shape the ethical behaviour of a professional. (Understand Level)
CO5	Explain the role and responsibility in technological development upholding personal ethics and legal ethics (Understand Level)

CO – PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1						✔		✔			✔	✔
CO2		✔	✔	✔				✔	✔		✔	✔
CO3								✔				✔
CO4								✔				✔
CO5						✔		✔				✔

Assessment Pattern				
Bloom's Category	**Continuous Assessment Tools**			**End Semester Examination**
	Test 1	**Test 2**	**Other tools**	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse				
Evaluate				
Create				
Mark Distribution of CIA				

Course Structure[L-T-P-J]	**Attendance**	**Theory [L-T]**			**Total Marks**
		Assignment	**Test-1**	**Test-2**	
3-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 hrs

End Semester Examination [ESE]: Pattern			
Pattern	**Part A**	**Part B**	**ESE Marks**

PATTERN 1	10 Questions, each question carries 2 marks Marks: (2×10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5×8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5×8 = 40 marks]	

SYLLABUS
MODULE I (FOUNDATION OF LIFE SKILLS)
Understanding Life Skills: Meaning and Significance of Life Skills-WHO-Identified Life Skills-Life skills for professionals Self-awareness: Definition and Need-Tools and Techniques of Self-awareness Stress Management: Stress, reasons and effects- stress diaries- Four A's of stress management

Coping with emotions: Identifying and managing emotions- PATH method and relaxation techniques (Group activities for self-awareness and stress management)
MODULE II (21ST CENTURY SKILLS AND PROBLEM SOLVING TECHNIQUES)
21st Century Skills: Creativity, Critical Thinking, Collaboration, Problem Solving, Decision Making- Lateral Thinking- Critical thinking Vs Creative thinking Problem Solving Techniques: Six Thinking Hats- Mind Mapping-Forced Connections Scientific temperament and Logical thinking with case studies. (Activity based learning)
MODULE III (GROUP DYNAMICS AND LEADERSHIP)

Group and Team Dynamics: Composition, Formation-Problem Solving in Groups-Group vs Team, Team Dynamics- Managing team performance(Activity based learning) Leadership: Leadership Framework -Types of Leadership- VUCA Leadership

Transactional vs Transformational Leaders

MODULE IV (HUMAN VALUES)

Morals, values and Ethics – Integrity- Academic integrity-Work Ethics- Service Learning Civic Virtue- Respect for others- Living peacefully- Caring and Sharing- Honestly courage-Cooperation commitment- Empathy-Self Confidence -Social Expectations. Case study on Engineering disasters (Include study of Ethical issues in a recent disaster) Code of Conduct in Engineering profession.

MODULE V (RESPONSIBILITIES AND RIGHTS)

Collegiality and loyalty – Managing conflict- Respect for authority- Collective bargaining Confidentiality-Role of confidentiality in moral integrity-Conflicts of interest Occupational crime- Professional rights-Employee right- IPR Discrimination Global ethical issues- Business ethics, Computer Ethics, Environment ethics – Role in technological development-Engineers as Managers- Consulting Engineers- Engineers as Expert witnesses and advisors.

Text books

1. Remesh S., Vishnu R.G., "Life Skills for Engineers", Ridhima Publication, First Edition 2016
2. ICT Academy of Kerala, "Life Skills for Engineers", McGraw Hill Education (India) Private Ltd., 2016
3. Mike W Martin and Roland Schinzinger, Ethics in Engineering, 4th edition, Tata McGraw Hill Publishing Company Pvt. Ltd, New Delhi,2014.

Reference books

1. Shiv Khera, You Can Win, Macmillan Books, New York, 2003
2. Barun K. Mitra, "Personality Development & Soft Skills", Oxford Publishers, Third impression, 2017.
3. Shalini Verma, "Development of Life Skills and Professional Practice"; First Edition; Sultan Chand (G/L) & Company, 2014
4. Charles D Fleddermann, Engineering Ethics, Pearson Education/ Prentice Hall of

India, New Jersey, 2004. 5. Charles E Harris, Michael S Protchard and Michael J Rabins, Engineering Ethics Concepts and cases, Wadsworth Thompson Learning, United states, 2005.		
COURSE CONTENTS AND LECTURE SCHEDULE		
No.		No. of
		Hours (36)
MODULE I (8 Hours)		
1.1	Understanding Life Skills: Meaning and Significance of Life Skills WHO-Identified Life Skills-Life skills for professionals	1
1.2	Self-awareness: Definition and Need-Tools and Techniques of Self awareness	1
1.3	Activity based on Self-awareness	1
1.4	Activity based on Self-awareness	1
1.5	Stress Management: Stress, reasons and effects- stress diaries Four A's of stress management	1
1.6	Coping with emotions: Identifying and managing emotions-PATH method and relaxation techniques	1
1.7	Activity based on Stress Management	1
1.8	Activity based on Stress Management	1
MODULE II (7 Hours)		
2.1	21st Century Skills: Creativity, Critical Thinking, Collaboration, Problem Solving	1
2.2	Decision Making- Lateral Thinking- Critical thinking Vs Creative thinking (1 hour for exercise)	1
2.3	Activity based on Lateral Thinking, Critical and Creative thinking	1
2.4	Problem Solving Techniques: Six Thinking Hats- Mind Mapping Forced Connections (2 hours for activity)	1
2.5	Activity based on problem solving techniques	1

2.6	Activity based on problem solving techniques	1
2.7	Scientific temperament and Logical thinking with case studies	1
	MODULE III (7 Hours)	
3.1	Group and Team Dynamics: Composition, Formation- Problem Solving in Groups	1
3.2	Group vs. Team, Team Dynamics- Managing team performance (2 hours for activity)	1

3.3	Activity based on Team Dynamics	1
3.4	Activity based on Team Dynamics	1
3.5	Leadership: Leadership Framework -Types of Leadership	1
3.6	VUCA Leadership	1
3.7	Transactional vs. Transformational Leaders	1
	MODULE IV (7 Hours)	
4.1	Morals, values and Ethics – Integrity- Academic integrity	1
4.2	Work Ethics- Service Learning- Civic Virtue- Respect for others Living peacefully	1
4.3	Honestly- courage-Cooperation commitment- Empathy	1
4.4	Self Confidence -Social Expectations.	1
4.5	Case study on Engineering disasters	1
4.6	Case study on Engineering disasters	1
4.7	Code of Conduct in Engineering profession	1
	MODULE V (7 Hours)	
5.1	Collegiality and loyalty – Managing conflict- Respect for authority	1
5.2	Collective bargaining- Confidentiality-Role of confidentiality in moral integrity	1
5.3	Conflicts of interest- Occupational crime	1

5.4	Professional rights-Employee right- IPR Discrimination	1
5.5	Global ethical issues- Business, Engineering, Environment.	1
5.6	Role in technological development-Engineers as Managers Consulting Engineers	1
5.7	Engineers as Expert witnesses and advisors.	1

CO Assessment Questions	
CO1	1. List 'life skills' as identified by WHO. 2. Explain the essential life skills required by a professional.
CO2	1. Illustrate the creative thinking process with the help of a suitable example 2. "Imagine you are tasked with addressing a complex environmental issue, such as reducing plastic waste in a coastal community”. How would you apply the Six Thinking Hats technique to explore different facets of the problem and generate potential solutions?
CO3	1. “A group focuses on individual contribution, while a team must focus on synergy.” Explain. 2. "Imagine you are part of a diverse team tasked with addressing a complex

	organizational challenge in a VUCA environment. Apply your knowledge of group formation and composition to strategically assemble a team that can effectively tackle the issue.
CO4	1. Define integrity and point out ethical values 2. Explain the role of engineers in modern society
CO5	1. Distinguish between self-interest and conflicts of interest 2. Explain the role of professional ethics in technological development.

24CHT307	PROCESS SAFETY	L	T	P	J	S	C	Year of Introduction
		2	0	0	0	2	2	2024

Preamble: The course "Process Safety" provides an understanding of the principles, practices, and methodologies involved in ensuring the safety and integrity of process industries. This course emphasizes the identification of hazards associated with chemical processes, with a focus on preventing incidents, protecting personnel, and safeguarding the environment.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to:

CO1	Describe the theories of accident causation and preventive measures of industrial accidents.
CO2	Suggest effective strategies for fire prevention.
CO3	Classify various types of hazards present in the process industries.
CO4	Explain personal protective equipment, its selection, safety performance & indicators, and the importance of housekeeping.
CO5	Analyze case studies related to the failure of process safety management system elements, contributing to incidents.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3											2
CO2	3					2						2
CO3	3					2				3		2
CO4	3					2		2				2
CO5	3					2		2				2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	
Understand	✔	✔	✔	
Apply	✔	✔	✔	
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	

2-0-0-0	5	35	30	30	100

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	100	x	x

SYLLABUS

MODULE I: Safety Introduction

Concept and importance of process safety; Definitions of process safety terms – Hazard, Risk, Accident, Injury, Unsafe act, Unsafe Condition, Dangerous Occurrence, and Reportable Accidents; Theories of accident causation.

MODULE II: Fundamentals of Fire Processes

Chemistry of fire; Fire triangle, and tetrahedron; Flammability limits, flash, and fire points; Ignition sources, and their characteristics; Types of fire, Fire prevention systems, and fire protection systems – Examples of Active Fire Protection Systems, Passive Fire Protection Systems, fire detection, and alarm systems.

MODULE III: Hazards in the Process Industries

Chemical Hazards – flammable chemicals, explosive chemicals, reactive chemicals, and toxic chemicals; Introduction to Physical Hazards, Electric Hazards, Mechanical Hazards, and Environmental Hazards; Provision of Hazard Information - Safety Data Sheets.

MODULE IV: Personal Protection in Work Environment

Personal protection in the work environment: Types of Personal protective equipment (PPEs), Standards related to PPEs; Monitoring Safety Performance: Frequency rate, severity rate, incidence rate, and activity rate; Housekeeping: Responsibility of management and employees, advantages of good housekeeping, 5S of housekeeping.

MODULE V: Case Study of Some Major Accidents in the World

Flixborough, UK - Brief description of facility and process, the accident, causes, circumstances, and consequences, Lessons/Recommendations;
Seveso, Italy - Brief description of facility and process, the accident, causes, circumstances, and consequences, Lessons/Recommendations;
Indian Oil Corporation product tank farm, Jaipur, India - Brief description of facility and process, the accident, causes, circumstances, and consequences, Lessons/Recommendations;
ISRO Sriharikota Space Launch Centre - Brief description of facility and process, the accident; causes, circumstances, and consequences, Lessons/Recommendations.

Textbooks

1. Daniel A. Crowl and Joseph F. Louvar, "Chemical Process Safety: Fundamentals with Applications"
2. S. K. Biswas, U. Mathur and S. K. Hazra, “Fundamentals of Process Safety Engineering”,

Reference books

1. Frank P. Lees, "Loss Prevention in the Process Industries: Hazard Identification, Assessment, and Control",
2. Ferguson L.H., Janicak C.A., “Fundamentals of fire protection for the safety professional”, Scarecrow (2005).
3. CCPS (Center for Chemical Process Safety), “Process Safety for Engineers: An Introduction”, Wiley (2022).

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE 1 (4 HOURS)		
1.1	Introduction to Process Safety and Definitions of Process Safety Terms	1
1.2	Hazard, Risk, Accident, Injury, Unsafe act, Unsafe Condition,	1
1.3	Dangerous Occurrence, and Reportable Accidents	1
1.4	Theories of accident causation.	1
MODULE II (6 HOURS)		
2.1	Chemistry of fire; Fire triangle, and tetrahedron	1
2.2	Flammability limits, flash, and fire points	1
2.3	Ignition sources, and their characteristics	1
2.4	Types of fire, Fire prevention systems,	1
2.5	Fire protection systems	1
2.6	Examples of Active Fire Protection Systems, Passive Fire Protection Systems, fire detection, and alarm systems.	1
MODULE III (5 HOURS)		
3.1	Chemical Hazards – flammable chemicals, explosive chemicals,	1
3.2	reactive chemicals,and toxic chemicals	1
3.3	Introduction to Physical Hazards, Electric Hazards	1
3.4	Introduction to Mechanical Hazards, and Environmental Hazards	1
3.5	Provision of Hazard Information - Safety Data Sheets.	1
MODULE IV (5 HOURS)		
4.1	Personal protection in the work environment: Types of Personal protective equipment (PPEs),	1
4.2	Standards related to PPEs	1
4.3	Monitoring Safety Performance: Frequency rate, severity rate, incidence rate, and activity rate	1
4.4	Housekeeping: Responsibility of management and employees	1
4.5	Advantages of good housekeeping, 5S of housekeeping	1
MODULE V (4 HOURS)		
5.1	Flixborough, UK - Brief description of facility and process, the accident, causes, circumstances, and consequences, Lessons/Recommendations;	1

5.2	Seveso, Italy - Brief description of facility and process, the accident, causes, circumstances, and consequences,	1
	Lessons/Recommendations;	
5.3	Indian Oil Corporation product tank farm, Jaipur, India - Brief description of facility and process, the accident, causes, circumstances, and consequences, Lessons/Recommendations	1
5.4	ISRO Sriharikota Space Launch Centre - Brief description of facility and process, the accident; causes, circumstances, and consequences, Lessons/Recommendations.	1

CO Assessment Sample Questions	
1	Read the following scenario and answer the questions that follow: Scenario: A chemical manufacturing plant recently experienced a process safety incident that resulted in a major release of toxic gases. The incident occurred during a routine maintenance activity on a reactor vessel. As a result of the release, several workers were exposed to the toxic gases, leading to injuries and hospitalizations. The incident also caused significant damage to the plant's equipment and infrastructure. (i) Identify the hazards associated with the incident described in the scenario. (ii) Analyze the potential root causes of the incident. Discuss any unsafe acts or conditions that might have contributed to the release of toxic gases. (iii) Explain the importance of effective communication and coordination during maintenance activities to prevent incidents like the one described. What communication failures or breakdowns might have occurred in this scenario? (iv) Discuss the immediate actions that should be taken following such an incident to ensure the safety of the affected workers, mitigate further risks, and initiate the investigation process.
2	Differentiate between the various types of fires based on the fuel involved, such as Class A, B, C, D, and K fires. Describe the appropriate fire extinguishing agents and strategies for each fire class.
3	Explain the characteristics and hazards associated with flammable chemicals. Discuss the factors that contribute to the flammability of chemicals and the precautions that should be taken to handle and store flammable substances safely.

4	Discuss the role of leadership in promoting a culture of safety, including the use of PPE, monitoring safety performance, and maintaining effective housekeeping. Explain how leadership behaviors and attitudes influence employee engagement and compliance with safety measures.
5	With respect to the Flixborough accident, answer the following questions: a) Provide a brief description of the facility and process involved in the Flixborough accident. b) Discuss the causes and circumstances that led to the Flixborough accident. c) Explain the consequences of the Flixborough accident in terms of human casualties, environmental impact, and property damage. d) Analyze the lessons learned from the Flixborough accident and provide recommendations for improving process safety in similar facilities.

THIRD SEMESTER
MINOR

24CHM309	INTRODUCTION TO CHEMICAL ENGINEERING	L	T	P	J	S	C	Year of Introduction
		4	0	0	0		4	2024

Preamble: This course familiarize students with the concepts of units and equations
of state. It also provides a brief overview of unit operations and unit processes, fluid flow operations, introduction to process instrumentation and control, safety in chemical process industries and environmental engineering.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Explain the history, role of chemical engineering and chemical engineering profession.
CO2	Explain the basic concept of units, dimensions, various methods of expressing compositions and equations of state.
CO3	Describe the basic concepts of flow diagrams, process instrumentation and control.
CO4	Analyse typical wastewater treatment system.
CO5	Explain the theories of accident causation and preventive measures of industrial accidents.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3											1
CO2	3	3										1
CO3	3											1
CO4	3					3	3					1
CO5	3					3	3					1

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
4-0-0-0	5	15	10	10	40

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Introduction

Introduction to Chemical engineering: history of Chemical engineering, role of Chemical engineering broad overview; Chemical industries in India; introduction to Chemical engineering profession; introduction to chemical plant operation; process development and process design.

MODULE II: Units, dimensions and mole concept

Basic concepts: units and dimensions, systems of units, conversion and conversion factors of units, concept of mole, weight percent, mole percent, normality, molarity, molality, vapour pressure, partial pressure, concept of ideal gas and equations of state.

MODULE III: Introduction to fluid flow, process instrumentation and control

Overview of unit operations and unit processes. Fluid flow – laminar and turbulent flow, introduction to transportation of fluids. Introduction to process instrumentation and control - Block diagram, Process flow diagram, basic concepts of P & I diagram, Measuring instruments: thermocouple, venturi meter, U-tube manometer.
MODULE IV: Introduction to Environmental Engineering
Introduction to Environmental Engineering- environmental legislation and regulation-water quality standards, Wastewater treatment methods - pretreatment - primary treatment - secondary treatment - tertiary treatment-advanced treatment methods. Typical air and solid waste management systems.
MODULE V: Introduction to safety in industries
Need for safety. Safety and productivity. Definitions: Accident, Injury, Unsafe act, Unsafe Condition, Dangerous Occurrence, Reportable accidents. Theories of accident causation. Safety organization- objectives, types, functions, Role of management, supervisors, workmen, unions, government and voluntary agencies in safety. Case study: Bhopal gas tragedy.
Text books 1. K. V. Narayanan and B. Lakshmikutty, "Stoichiometry and Process Calculations", PHI learning Pvt. Ltd., Delhi 2. R.K Jain (2000) Industrial Safety, Health and Environment management systems, Khanna Publications.
Reference books 1. Badger and Bachero, "Introduction to Chemical Engineering", McGraw Hill 2. McCabenW.L., Smith J.C. and Harriott P. "Unit Operations in Chemical Engineering", McGraw Hill 3. Pushpavanam S., "Introduction to Chemical Engineering", PHI Learning Pvt. Ltd.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE 1 (6 hours)		
1.1	Introduction to Chemical engineering: history of Chemical engineering	1
1.2	Role of Chemical engineering broad overview	1
1.3	Chemical industries in India	1
1.4	Introduction to Chemical engineering profession	1

1.5	Introduction to chemical plant operation	1
1.6	Process development and process design	1
MODULE II (6 hours)		
2.1	Units and dimensions, systems of units	1
2.2	Conversion and conversion factors of units	1
2.3	Concept of mole, weight percent	1
2.4	Mole percent, normality	1
2.5	Molarity, molality, vapour pressure	1
2.6	Partial pressure, concept of ideal gas and equations of state.	1
MODULE III (8 hours)		
3.1	Overview of unit operations and unit processes	1
3.2	Laminar and turbulent flow	1
3.3	Introduction to transportation of fluids	1
3.4	Introduction to process instrumentation and control	1
3.5	Block diagram, Process flow diagram	1
3.6	Basic concepts of P & I diagram	1
3.7	Measuring instruments: thermocouple	1
3.8	Venturi meter, U-tube manometer	1
MODULE IV (7 hours)		
4.1	Environmental legislation and regulation	1
4.2	Water quality standards	1
4.3	Wastewater treatment methods - pretreatment	1
4.4	Primary treatment, secondary treatment	1
4.5	Tertiary treatment, advanced treatment methods	1
4.6	Typical air pollution management systems.	1
4.7	Typical solid waste management systems.	1
MODULE V (7 hours)		
5.1	Need for safety	1
5.2	Safety and productivity	1
5.3	Definitions: Accident, Injury, Unsafe act, Unsafe Condition, Dangerous Occurrence, Reportable accidents	1

5.4	Theories of accident causation	1
5.5	Safety organization- objectives, types, functions	1
5.6	Role of management, supervisors, workmen, unions, government and voluntary agencies in safety	1
5.7	Case study: Bhopal gas tragedy	1

CO Assessment Sample Questions	
1	Discuss the role of chemical engineers in controlling atmospheric pollution.
2	The mass velocity of a gas through a duct is 1000 kg/m^2h. Express the velocity in lb/ft^2s.
3	Explain the principle of venturi meter.
4	Describe the different methods of solid waste disposal practiced in India.
5	Explain the importance of safety measures in chemical industries with the help of Bhopal gas tragedy.

FOURTH SEMESTER

24CHT401	Chemical Engineering Thermodynamics	L	T	P	J	S	C	Year of Introduction
		3	1	0	0	3	4	2024

Preamble:

This course aims to impart the basic concepts of Classical Thermodynamics. The topics included in the course are laws of Thermodynamics and their applications to open and closed systems and property relations for pure substances and solutions, concepts of Ideal and Non ideal solutions, phase equilibrium with special emphasis to Vapour Liquid Equilibria, Activity coefficient models and Chemical Reaction Equilibria. The major focus is to build a strong foundation in the subject and to familiarize with the applications of thermodynamic principles in chemical engineering problems.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Apply laws of thermodynamics to analyze various process.
CO2	Explain thermodynamics properties, process and states of a system.
CO3	Calculate the thermodynamic properties of ideal/real gases and mixtures/solutions.
CO4	Explain VLE of completely miscible, partially miscible and immiscible liquids.
CO5	Calculate equilibrium constant and composition of reactions taking place under given conditions.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3										2
CO2	3	3										2
CO3	3	3										2
CO4	3	3			2							2
CO5	3	3										2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	**Attendance**	**Theory [L- T]**			**Total Marks**
		Assignment	**Test-1**	**Test-2**	
3-1-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 Hrs

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Thermodynamic system and First law of thermodynamics

Overview of thermodynamics and its applications in chemical engineering: Basic terms and definitions: Thermodynamic system – Open/Closed; Thermodynamic properties- Extensive/Intensive, state; process (definition and types); state/path functions- phase; Measurable properties - Temperature, Pressure & volume; Concept of Equilibrium- types- general conditions for equilibrium; Independent/dependent thermodynamic properties – Gibbs phase rule; PVT relationship for pure substances; phase diagram – triple line- critical properties- saturation pressure – vapour pressure. Laws of thermodynamics: First law (statement) – forms of energy – work and heat; internal energy; Thermodynamic paths – reversible & irreversible processes (work, heat calculation) – use of hypothetical paths First law for closed and open systems (Energy balance equation derivation) – Enthalpy – Heat Capacity; Energy transfer during reversible processes in closed system – isothermal expansion/compression, adiabatic expansion/compression; Application of 1st law in process equipment: Nozzles; Thermodynamic cycles – Carnot cycle.
MODULE II: Second law of thermodynamics, Equation of States (EOS) & Property relations
Limitations of 1st law – Directionality of process - Second Law of thermodynamics - Carnot principles; Entropy – calculation of entropy change in closed/open system for ideal gases; Vapour compression refrigeration cycles. Equation of States: Overview of intermolecular forces; Ideal gas equation – Compressibility factor; Equation of States for real gases- van der Waals equation, Redlich Kwong equation, virial equation; Principle of corresponding states; generalized compressibility charts. Thermodynamic Property Relations: Types of thermodynamic properties – Measured/fundamental/derived, dependent/independent; fundamental property relations – Maxwell’s equations; Relations for entropy change, internal energy change and enthalpy change in terms of independent variable (T,P & V); Calculation of entropy change, internal energy change and enthalpy change using EOS; Concept of departure functions(limited to definition); Joule Thomson expansion.
MODULE III: Phase Equilibria

Phase equilibrium of pure species – Gibbs free energy – Criteria of Chemical equilibrium in terms of Gibbs free energy; Relation between saturation pressure and temperature (Clapeyron equation); Clausius Clapeyron equation. Phase equilibria in mixtures – Partial molar properties; Chemical potential; Gibbs-Duhem equations; property change of mixing (general expression and for ideal gases); Determination of partial molar properties (analytic method only, numerical limited to the application of van der Waals equation); Criteria of chemical equilibrium in terms of chemical potential; temperature and pressure dependence of chemical potential. Fugacity – Criteria of chemical equilibrium in terms of fugacity; Ideal gas; fugacity and fugacity coefficient for pure gases (using EOS & generalized correlations), gas mixtures; Lewis fugacity rule; Ideal solution; Lewis/ Randall rule; Henry's law. Activity coefficient; Calculation of pure species fugacity – pointing correction factor; relation for activity coefficient from Gibbs-Duhem equations; Concept of excess properties; Excess Gibbs free energy.
MODULE IV : Activity Coefficient model & Applications of Phase equilibria
Models for activity coefficient using excess Gibbs free energy- 2-suffix Margules equation, van Laar equation. Concept and applications of other activity coefficient models – Wilson equation, NRTL, UNIQAC;(limited to applications-equations not required). Vapour Liquid Equilibria: Raoult's law & modified Raoult's law; K-value; bubble point, dewpoint and flash calculations; Non-ideal liquids; Azeotropes. Overview of Liquid-liquid equilibrium. Vapour-Liquid-liquid Equilibrium - Phase diagrams of partially miscible and
immiscible systems; Colligative properties- Boiling point elevation/freezing point depression.
MODULE V : Chemical reaction equilibria
Standard Gibbs energy of reaction; Equilibrium for a single reaction stoichiometric coefficient, extent of reaction, reaction coordinate; Equilibrium constant and its temperature dependence; Relation of equilibrium constant to compositions involving gas phase; Equilibrium constant for liquid phase/solid phase reactions; Equilibrium constant for heterogeneous reactions; Effect of pressure and other parameters on conversion; multi-reaction equilibria.
Text books 1. Milo D. Koretsky, Engineering and Chemical Thermodynamics, 2nd Edn, Wiley, 2012

Reference books		
1. Smith J. M. & Van Ness H.V., Introduction to Chemical Engineering Thermodynamics, 8th Edn, McGraw Hill, 2018. 2. Narayanan K. V., A Textbook of Chemical Engineering Thermodynamics, 2nd Edn., Prentice Hall of India, 2013. 3. Stanley I. Sandler, Chemical and Engineering Thermodynamics, 2nd Edn., John Wiley & Sons,USA, 1989 4. Kyle B.G., Chemical and Process Thermodynamics, 3rd Edn, Prentice-Hall, 1999 5. Y.V.C. Rao, Chemical Engineering Thermodynamics, Universities Press, 1997		
COURSE CONTENTS AND LECTURE SCHEDULE		
No.		No. of Hours
MODULE 1 (10 hours)		
1.1	Basic terms and definitions: Thermodynamic system – Open/Closed; Thermodynamic properties- Extensive/Intensive, state; process (definition and types); state/path functions- phase.	1
1.2	Measurable properties - Temperature, Pressure & volume; Concept of Equilibrium- types- general conditions for equilibrium; Independent/dependent thermodynamic properties – Gibbs phase rule.	1
1.3	PVT relationship for pure substances; phase diagram – triple line- critical properties- saturation pressure – vapour pressure.	1
1.4	First law (statement) – forms of energy – work and heat; internal energy; Thermodynamic paths – reversible & irreversible processes (work, heat calculation) – use of hypothetical paths.	1
1.5	First law (statement) – forms of energy – work and heat; internal energy; Thermodynamic paths – reversible & irreversible processes (work, heat calculation) – use of hypothetical paths.	1
1.6	First law for closed and open systems (Energy balance equation derivation).	1
1.7	Enthalpy – Heat Capacity; Energy transfer during reversible processes in closed system – isothermal expansion/compression, adiabatic expansion/compression.	1

1.8	Enthalpy – Heat Capacity; Energy transfer during reversible processes in closed system – isothermal expansion/compression, adiabatic expansion/compression.	1
1.9	Application of 1st law in process equipment: Nozzles; Thermodynamic cycles – Carnot cycle.	1
1.10	Application of 1st law in process equipment: Nozzles; Thermodynamic cycles – Carnot cycle.	1
MODULE II (10 hours)		
2.1	Limitations of 1st law – Directionality of process - Second Law of thermodynamics - Carnot principles.	1
2.2	Entropy – calculation of entropy change in closed/open system for ideal gases; Vapour compression refrigeration cycles.	1
2.3	Overview of intermolecular forces; Ideal gas equation – Compressibility factor; Equation of States for real gases-van der Waals equation, Redlich Kwong equation, virial equation.	1
2.4	Principle of corresponding states; generalized compressibility charts.	1
2.5	Types of thermodynamic properties Measured/fundamental/derived, dependent/independent; fundamental property relations – Maxwell's equations.	1
2.6	Types of thermodynamic properties Measured/fundamental/derived, dependent/independent; fundamental property relations – Maxwell's equations.	1
2.7	Relations for entropy change, internal energy change and enthalpy change in terms of independent variable (T, P & V).	1
2.8	Calculation of entropy change, internal energy change and enthalpy change using EOS.	1
2.9	Calculation of entropy change, internal energy change and enthalpy change using EOS.	1
2.10	Concept of departure functions (limited to definition); Joule Thomson expansion.	1
MODULE III(10 hours)		

3.1	Gibbs free energy – Criteria of Chemical equilibrium in terms of Gibbs free energy.	1
3.2	Relation between saturation pressure and temperature (Clapeyron equation); Clausius Clapeyron equation.	1
3.3	Partial molar properties; Chemical potential; Gibbs-Duhem equations; property change of mixing (general expression and for ideal gases).	1
3.4	Determination of partial molar properties (analytic method only, numerical limited to the application of van der Waals equation).	1
3.5	Criteria of chemical equilibrium in terms of chemical potential; temperature and pressure dependence of chemical potential.	1
3.6	Fugacity – Criterial of chemical equilibrium in terms of fugacity; Ideal gas; fugacity and fugacity coefficient for pure gases (using EOS & generalized correlations).	1
3.7	Fugacity – Criterial of chemical equilibrium in terms of fugacity; Ideal gas; fugacity and fugacity coefficient for pure gases (using EOS & generalized correlations).	1
3.8	gas mixtures; Lewis fugacity rule; Ideal solution; Lewis/ Randall rule; Henry's law.	1
3.9	Activity coefficient; Calculation of pure species fugacity – pointing correction factor; relation for activity coefficient from Gibbs-Duhem equations; Concept of excess properties; Excess Gibbs free energy.	1
3.10	Activity coefficient; Calculation of pure species fugacity – pointing correction factor; relation for activity coefficient from Gibbs-Duhem equations; Concept of excess properties; Excess Gibbs free energy.	1
MODULE IV (8 hours)		
4.1	Models for activity coefficient using excess Gibbs free energy- 2-suffix Margules equation, van Laar equation.	1
4.2	Models for activity coefficient using excess Gibbs free energy-	1

	2-suffix Margules equation, van Laar equation.	
4.3	Concept and applications of other activity coefficient models – Wilson equation, NRTL, UNIQAC;(limited to applications-equations not required).	1
4.4	Raoult's law & modified Raoult's law; K-value; bubble point, dewpoint and flash calculations.	1
4.5	Raoult's law & modified Raoult's law; K-value; bubble point, dewpoint and flash calculations.	1
4.6	Non-ideal liquids; Azeotropes Overview of Liquid-liquid equilibrium.	1
4.7	Phase diagrams of partially miscible and immiscible systems.	1
4.8	Colligativeproperties- Boiling point elevation/freezing point depression.	1
MODULE V (8 hours)		
5.1	Standard Gibbs energy of reaction; Equilibrium constant and its temperature dependence.	1
5.2	Standard Gibbs energy of reaction; Equilibrium constant and its temperature dependence.	1
5.3	Relation of equilibrium constant to compositions involving gas phase.	1
5.4	Relation of equilibrium constant to compositions involving gas phase.	1
5.5	Equilibrium constant for liquid phase/solid phase reactions; Equilibrium constant for heterogeneous reactions.	1
5.6	Equilibrium constant for liquid phase/solid phase reactions; Equilibrium constant for heterogeneous reactions.	1
5.7	Effect of pressure and other parameters on conversion; multi-reaction equilibria.	1
5.8	Effect of pressure and other parameters on conversion; multi-reaction equilibria.	1

CO Assessment Sample Questions	
1	Water at 90°C flowing at the rate of 2 kg/s mixes adiabatically with another stream at 30°C flowing at the rate of 1 kg/s. Estimate the rate of entropy generation and rate of energy loss due to mixing. Take T = 300 K
2	Using Redlich-Kwong equation determine the molal volumes of saturated liquid and saturated vapour of toluene at 300 K. The saturation pressure of methyl chloride at 300 K is 2 bar. The critical temperature and pressure are respectively 591.8 K and 41.09 bar.
3	The azeotrope of the n-propanol-water system has a composition 56.83% water with a boiling point of 360.9 K at a pressure of 101.3 kPa. At this temperature, the vapour pressures of water and propanol respectively are 64.25 kPa and 60.7 kPa. Evaluate the activity coefficients for a solution containing 20% water through the Van Laar equations.
4	The need arises in a laboratory for 2000 cm^3 of an antifreeze solution consisting of 30 mol % methanol in water. Determine the volumes of pure methanol and pure water at 25°C to be mixed to form 2000 cm^3 of antifreeze at 25°C.
5	The reaction is $N_2(g) + O_2(g) \rightarrow 2\,NO(g)$ is carried out at 2700°C and 2025 kPa. The reaction mixture initially comprises of 25 mol% oxygen, 65 mol% nitrogen and the rest an inert gas. The standard Gibbs free energy change for the reaction is 113.83 kJ/mol at the given conditions. Calculate the partial pressures of all species in the equilibrium reaction mixture. Make suitable assumptions, if required.

24CHT402	NUMERICAL METHODS FOR CHEMICAL ENGINEERS	L	T	P	J	S	C	Year of Introduction
		2	1	0	0	2	3	2024

Preamble: Numerical Methods use computers to solve problems by step-wise, repeated and iterative solution methods, which would otherwise be tedious or unsolvable by hand calculations. This course is designed to give an overview of numerical methods of interest to scientists and engineers. The course aims at giving adequate exposure to methods for numerically solving algebraic and transcendental equations, system of linear and non-linear equations, polynomial interpolation, integration, differentiation and differential equations.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to:

CO1	Identify the errors and its effect on numerical computations and solve polynomial and transcendental equation using an appropriate numerical method.
CO2	Solve linear and non-linear algebraic system of equations using an appropriate numerical method.
CO3	Apply different numerical methods for interpolation, differentiation and integration of functions.
CO4	Solve differential equations by different numerical methods.
CO5	Apply numerical techniques for solving chemical engineering problems.
CO6	Utilize the standard point-and-shoot numerical problem-solving capabilities of packages like Excel or MATLAB or Mathcad or any similar software.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3			3							2
CO2	3	3			3							2
CO3	3	3			3							2
CO4	3	3			3							2
CO5			2									3
CO6					3							3

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA					
Course Structue [L-T-P-J]	**Attendance**	**Theory [L- T]**			**Total Marks**
		Assignment	**Test-1**	**Test-2**	
2-1-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 hours
End Semester Examination (ESE) Pattern:			
PATTERN	**PART A**	**PART B**	**ESE Marks**
Pattern 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x8=40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: 5 x 8 = 40	
SYLLABUS			
MODULE I: Error analysis and Solution of non-linear equation			
Errors in numerical calculations: Significant figures, Accuracy and Precision, Error definitions and numerical instability. Numerical solution of non-linear equations by bracketing (Bisection and False-Position) methods. Numerical solution of non-linear equations by open end (Fixed-point iteration and its convergence, Newton-Raphson and its convergence, Secant) methods. Case Studies: Roots of equations – Ideal and non-ideal gas laws, pipe friction. Solution of any two methods using software packages (Not included for test / end semester examination).			
MODULE II: Solution of system of linear and non-linear algebraic equations			
Numerical solution of simultaneous linear algebraic equations: Direct Methods – Gauss Elimination, Gauss Jordan and LU Decompositions (Doolittle Decomposition and Crout Decomposition). Iterative Methods – Jacobi iteration, Gauss-Seidal, Relaxation. Solution of system of non-linear equations by Newton-Raphson method. Case Study: Steady state analysis of a system of reactors. Solution of any two methods using software packages (Not included for test / end semester examination).			
MODULE III: Numerical interpolation, integration and differentiation			
Polynomial interpolation. Lagrange's interpolation polynomial - divided differences			

Newton's divided difference interpolation polynomial - error of interpolation – finite difference operators - Gregory–Newton forward and backward interpolations. Numerical integration – Trapezoidal rule and Simpson's rules. Numerical differentiation using Newton's forward and backward formula. Case Study: Integration to determine the total quantity of heat. Solution of any two methods using software packages (Not included for test / end semester examination).

MODULE IV: Solution of Ordinary Differential Equations

Numerical solution of ordinary differential equations: Euler's method and Modified Euler's method, Runge–Kutta methods (2nd order and 4th order only) - multistep methods - Adam-Bashforth and Adam-Moulton formula. Solution of boundary value problems in ordinary differential equations - Finite difference method. Case Study: Use of ordinary differential equation to analyze the transient response of a unit process / operation. Solution of any two methods using software packages (Not included for test / end semester examination).

MODULE V: Solution of Partial Differential Equations

Numerical solution of partial differential equations: Solution of Laplace equation using Jacobi's and Liebmann's method. Solution of heat conduction equation using Schmidth and Crank-Nicolson method. Solution of wave equation with given boundary conditions. Case Study: One-Dimensional mass balance of a reactor/other suitable problem related to solution of partial differential equation. Solution of any two methods using software packages (Not included for test / end semester examination).

Textbooks

1. Steven C Chapra and Raymond P Canale, Numerical Methods for Engineers, 8th Edition, Mc Graw Hill.
2. Pradeep Ahuja, Numerical Methods in Chemical Engineering, PHI
3. Gerald C.F. and Wheatly P.O., Applied Numerical Analysis, Pearson
4. Jain M.K., Iyengar S.R.K. and Jain R.K., Numerical Methods for Scientific and Engineering Computation, New Age International

Reference books

1. Ajay K. Ray, Mathematical Methods in Chemical & Environmental Engineering, Thomson-Learning
2. Froberg C.E., Introduction to Numerical Analysis, Addison Wesley
3. Rajaraman V, Computer Oriented Numerical Methods, PHI
4. Hildebrand F.B., Introduction to Numerical Analysis, TMH
5. James M.L., Smith C.M. & Wolford J.C., Applied Numerical Methods for Digital Computation, Harper & Row
6. Mathew J.H., Numerical Methods for Mathematics, Science and Engineering, PHI

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE I (7 hours)		
1.1	Introduction to Numerical Methods. Errors in numerical calculations: Significant figures, Accuracy and Precision.	1
1.2	Error definitions and numerical instability.	1

1.3	Numerical solution of non-linear equations by bracketing method - Bisection	1
1.4	False Position Method. Numerical solution of non-linear equations by open end method – Fixed point iteration and its convergence	1
1.5	Newton-Raphson and its convergence, Secant Method	1
1.6	Case Studies: Roots of equations – Ideal and non-ideal gas laws, pipe friction.	1
1.7	Solution of any two methods using software packages.	1
MODULE II (6 hours)		
2.1	Numerical solution of simultaneous linear algebraic equations: Direct Methods – Gauss Elimination, Gauss Jordan	1
2.2	LU Decompositions (Doolittle Decomposition and Crout Decomposition).	1
2.3	Iterative Methods – Jacobi iteration, Gauss-Seidal	1
2.4	Relaxation. Solution of system of non-linear equations by Newton-Raphson method.	1
2.5	Case Study: Steady state analysis of a system of reactors.	1
2.6	Solution of any two methods using software packages.	1
MODULE III (9 hours)		
3.1	Polynomial interpolation. Lagrange's interpolation polynomial	1
3.2	Divided differences. Newton's divided difference interpolation polynomial - error of interpolation	1
3.3	Finite difference operators, Gregory – Newton forward interpolations.	1
3.4	Gregory–Newton backward interpolations. Numerical integration – Trapezoidal rule.	1
3.5	Numerical integration – Simpson's rules.	1
3.6	Numerical differentiation using Newton's forward formula.	1
3.7	Numerical differentiation using Newton's backward formula.	1
3.8	Case Study: Integration to determine the total quantity of heat.	1
3.9	Solution of any two methods using software packages.	1
MODULE IV (7 hours)		
4.1	Numerical solution of ordinary differential equations: Euler's method and Modified Euler's method	1
4.2	Runge–Kutta method (2nd order)	1
4.3	Runge–Kutta method (4th order)	1
4.4	Multistep methods - Adam-Bashforth and Adam-Moulton formula	1
4.5	Solution of boundary value problems in ordinary differential equations - Finite difference method.	1
4.6	Case Study: Use of ordinary differential equation to analyze the transient response of a unit process / operation.	1
4.7	Solution of any two methods using software packages.	1

MODULE V (7 hours)		
5.1	Numerical solution of partial differential equations: Solution of Laplace equation using Jacobi's and Liebmann's method.	1
5.2	Solution of Laplace equation using Jacobi's and Liebmann's method.	1
5.3	Solution of heat conduction equation using Schmidth and Crank-Nicolson method.	1
5.4	Solution of heat conduction equation using Schmidth and Crank-Nicolson method.	1
5.5	Solution of wave equation with given boundary conditions.	1
5.6	Case Study: One-Dimensional mass balance of a reactor/other suitable problem related to solution of partial differential equation.	1
5.7	Solution of any two methods using software packages.	1

CO Assessment Sample Questions	
1a	Consider a ring-shaped conductor having total charge, Q. The radius of the ring is r. A charge q is located at a distance x from the centre of the ring. The force exerted by the ring on the charge is $F = \left[\frac{1}{4\pi\varepsilon_0}\right]\left[\frac{qQx}{(x^2+r^2)^{3/2}}\right]$ where $\varepsilon_0 = 8.85 \times 10^{-6}\ {}^{2}N^{-1}m^{-2}$. The radius of the ring is 1 m. Find the force at a distance of 50 cm if the values of q and Q are both 1 x 10-5 C. Round off the value at the third decimal place. Compute the force with the result rounded at the sixth decimal place. Compute relative error.
1b	A long electrically conducting metal rod having diameter D and electrical resistance R per unit length is placed in a large enclosure. The walls of the enclosure are far way from the rod. They are kept at a temperature Tw. The temperature of air flowing past the rod is Ta. If an electrical current I passes through the rod, the steady state temperature (T) of the rod can be found by solving the equation $\pi\{h(T - T_a) + \emptyset\sigma(T^4 - T_w^4)\} - I^2R = 0$. In this equation, h is the heat transfer coefficient, σ is Stefan Boltzmann constant and ∅ is the emissivity of the rod surface. Use the following data to obtain the steady state temperature T, by applying Newton Raphson method. σ = 5.67 x 10-8, ∅ = 0.8, h = 25, Ta = Tw = 298, D = 0.12, $I^2R = 150$. The initial estimate of the root is 298 and the error tolerance is 10-10.
2	Apply Gauss-Jordan method to solve the following system of equations: $x + y + z = 9$ $2x - 3y - 4z = 13$ $3x + 4y + 5z = 40$
3	The velocity of a rocket can be computed from the following formula

	$v = 2\times10^3 \ln\left[\frac{10^5}{10^5 - 2\times10^3 t}\right] - 10t$, where v is in m/s and t is in seconds. Find an estimate of the distance the rocket will travel in 30 seconds, using Simpson's 1/3 rule.
4	Solve the equation below subject to the initial condition $(x, y, 0) = \sin 2\pi x \sin 2\pi y$, $0 \le x, y \le 1$, and the conditions $u(x, y, t) = 0$, $t > 0$ on the boundaries. $$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}$$ Obtain the solution up to three time level with $h = \frac{1}{3}$ and $\alpha = \frac{1}{8}$
5	Ethane may be assumed to obey the van der Waals equation of state, i.e., the pressure of one mole of gas occupying volume V at temperature T is given by $P = \frac{T}{V-b} - \frac{a}{V^2}$ where R is the gas constant, 0.082 litre atm mol-1 K-1. The work done in isothermal compression of 1 mol of the gas from volume Vi to Vf is $W = \int_{V_i}^{V_f}\left[\frac{RT}{V-b} - \frac{a}{V^2}\right]dV$. For ethane, a = 5.5 atm litres2 mol-2 and b = 0.065 litre mol-1. Estimate the work done for compressing the gas from 20 litres to 5 litres at temperature 300 K.
6	Solve the equation $x - \cos x = 0$ by implementing the bisection method using a software tool. The lower and upper limits of the interval may be taken as 0 and 1, respectively. Terminate the computation of the root when the errors between two consecutive trials become 0.000001.

24CHP403	Fluid & Particle Mechanics	L	T	P	J	S	C	Year of Introduction
		2	1	2	0	4	4	2024

Preamble: This course is designed to cultivate a comprehensive understanding of
fluid and particle mechanics, with a specific focus on their applications in the field of chemical engineering. It encompasses fundamental concepts such as fluid properties, momentum transfer, and particle distribution, all of which are integral to the process design in chemical engineering. The course will delve into the intricacies of flow in boundary layers, guiding students in understanding and applying these concepts. Moreover, students will learn to select appropriate flow measuring devices and fluid-moving machineries, essential skills for professionals in the chemical engineering sector. By the end of this course, students will have a robust understanding of fluid and particle mechanics, enabling them to apply these principles effectively in the operation of processes within the chemical
engineering field.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Apply the basic properties and transport laws to fluid in different conditions like statics and dynamics.
CO2	Apply suitable forms of the mass, momentum and energy balance equations for solution of numerical problems in fluid flow.
CO3	Calculate major and minor losses in pipe flow.
CO4	Design a fluidized bed and a packed bed using the concept of fluid dynamics considering its application.
CO5	Select valves, pumps and flow measuring devices in process industries with the knowledge of the basic principles.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	3	3							2	2		2
CO 2	3	3										2
CO 3	3	3		3				2	3	3		2
CO 4	3	3		3				2	3	3		2
CO 5	3	3		3				2	3	3		2

Assessment Pattern for Theory component

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔

Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyze			✔	
Evaluate			✔	
Create			✔	

Assessment Pattern for Lab component

Bloom's Category	Continuous Assessment Tools	
	Class work	Test1
Remember		
Understand	✔	✔
Apply	✔	✔
Analyse	✔	✔
Evaluate	✔	
Create	✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Practical [P]		Total Marks
		Assignment	Test-1	Test-2	Class work	Lab Exam	
2-1-2-0	5	10	10	10	15	10	60

Total Marks distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	60	40	2.5 Hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 2		2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x 8 = 40 marks) Time: 2.5 hours	40
	Total Marks: 0	Total Marks: [5x8 = 40 marks]	

SYLLABUS
MODULE I: Properties, classification of fluid and Fluid statics
Introduction to process fluid mechanics; Definition and properties (density and specific heat) of fluid; Continuum hypothesis; Velocity field; Stress field; Newtonian, non-Newtonian fluids and viscoelastic fluid. Fluid statics: pressure variation in a static fluid, Hydrostatic forces on submerged surfaces. Buoyancy; Illustration by examples.
MODULE II: Introduction to fluid flow and Basic equations of fluid flow
Macroscopic Balances: Derivation of integral balances for mass, energy and momentum. Derivation of Bernoulli equation with losses. Application of macroscopic balances: Losses in expansion, Force on a reducing bend, Diameter of a free jet; Jet ejector. Differential balances of fluid flow: derivation of continuity and momentum (Navier-Stokes) equations for a Newtonian fluid. Applications to plane Couette, plane Poiseuille and pipe flows.
MODULE III: Internal flow of incompressible fluids in pipes and conduits
Dimensional analysis and similitude: Buckingham Pi-theorem and applications. High-Reynolds number flows: inviscid flows and potential flows. Boundary layer theory: Boundary-layer formation in straight tubes, Boundary-layer separation and wake formation. Pipe flows and fittings: laminar and turbulent flows, velocity distribution, universal velocity-distribution. Friction factor charts, losses in fittings, flow in manifolds.
MODULE IV: Flow past immersed bodies (External flow)
Flow past immersed bodies: flow past a sphere and other submerged objects. Drag coefficient. Solid–fluid contacting systems. Flow through packed beds: Ergun equation -Kozney-Carman equation - Blake Plummer equation. Flow through fluidized beds: Type of fluidization, Different regimes of fluidization, Advantages and disadvantages of fluidized beds and packed bed. Agitation and mixing: power consumption, mixing times, scale up.
MODULE V: Fluid Transportation
Flow measurement: Principle and working of Orifice meter, venturi meter, Pitot tube, Rotameters, Weirs and Notches (derivation not required). Brief introduction to non-conventional methods: Laser Doppler velocimetry, Particle image velocimetry, ultrasonic flow meters, electromagnetic flow meters (description only) Pumps and compressors: Classification.

Text books

1. R. W. Fox and A. T. McDonald, Introduction to Fluid Mechanics (6th Edition), John Wiley & Sons, U.S.A (2003).
2. J. O. Wilkes, Fluid Mechanics for Chemical Engineers, Prentice Hall (1999).
3. McCabe W.L., Smith J.C., Harriot P., Unit Operations of Chemical Engg. McGraw Hill.
4. Coulson J.M. & Richardson J.F., Chemical Engg. Vol. 1, Pergamon.

Reference books

1. Foust AS, Wenzel LA, Clump CW, Maus L, Andersen LB. Principles of unit operations. John Wiley & Sons.
2. Noel de Nerves, Fluid Mechanics for Chemical Engineers, McGraw Hill.
3. Streeter V.L., Fluid Mechanics, McGraw Hill.
4. Frank M. White, Fluid mechanics. McGraw Hill.
5. Y. Nakayama, Fluid mechanics. Butterworth-Heinemann.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1	
1.1	Introduction to process fluid mechanics, Definition and properties (density and specific heat)	1
1.2	Continuum hypothesis; Velocity field; Stress field	1
1.3	Newtonian and non-Newtonian fluids and viscoelastic fluid.	1
1.4	Fluid statics: pressure variation in a static fluid	1
1.5	Fluid statics: pressure variation in a static fluid	1
1.6	Hydrostatic forces on submerged surfaces	1
1.7	Buoyancy; Illustration by examples	1
	MODULE II	
2.1	Macroscopic Balances: derivation of integral balances for mass, energy and momentum	1
2.2	Derivation of engineering Bernoulli equation with losses.	1
2.3	Derivation of engineering Bernoulli equation with losses.	1
2.4	Application of macroscopic balances: Losses in expansion, Force on a reducing bend.	1
2.5	Diameter of a free jet; Jet ejector	1
2.6	Differential balances of fluid flow: derivation of continuity and momentum (Navier-Stokes) equations for a Newtonian fluid.	1

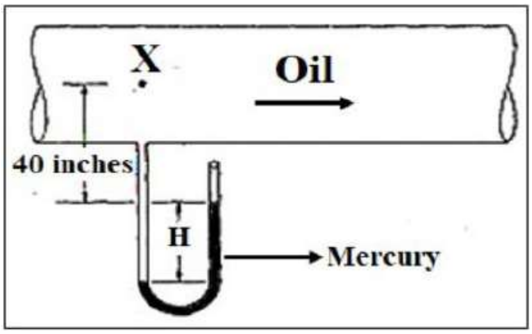
2.7	Applications to plane Couette, plane Poiseuille and pipe flows.	1
MODULE III		
3.1	Dimensional analysis and similitude: Buckingham Pi-theorem and applications.	1
3.2	High-Reynolds number flows: inviscid flows and potential flows.	1
3.3	Boundary layer theory: Boundary-layer formation in straight tubes.	1
3.4	Boundary-layer separation and wake formation.	1
3.5	Pipe flows and fittings: laminar and turbulent flows, velocity distribution.	1
3.6	Universal velocity-distribution-Friction factor charts.	1
3.7	Losses in fittings, flow in manifolds.	1
MODULE IV		
4.1	Flow past immersed bodies: flow past a sphere and other submerged objects. Drag coefficient. Solid–fluid contacting systems.	1
4.2	Flow through packed beds: Ergun equation -Kozney-Carman equation - Blake Plummer equation.	1
4.3	Flow through fluidized beds: Type of fluidization	1
4.4	Flow through fluidized beds: Type of fluidization	1
4.5	Different regimes of fluidization,	1
4.6	Advantages and disadvantages of fluidized beds and packed bed	1
4.7	Agitation and mixing: power consumption, mixing times, scale up.	1
MODULE V		
5.1	Flow measurement (derivation not required): Principle and working of Orifice meter, venturi meter	1
5.2	Pitot tube, Rotameters	1
5.3	Weirs and Notches.	1
5.4	Brief introduction to non-conventional methods: Laser Doppler velocimetry, Particle image velocimetry, ultrasonic flow meters, electromagnetic flow meters	1

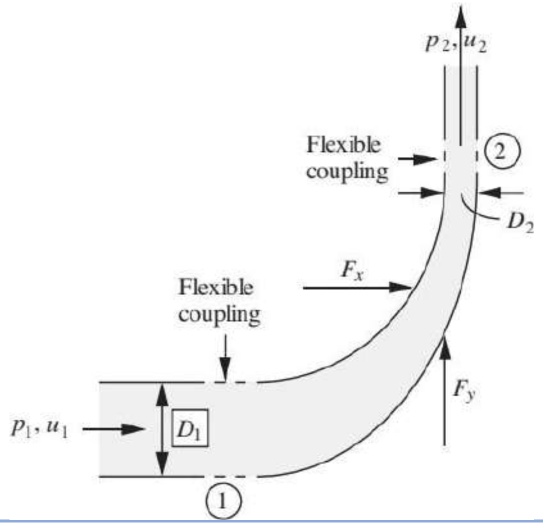
	(description only).	
5.5	Pumps and compressors: Classification	1

LESSON PLAN FOR LAB COMPONENT

No.	Topic	No. of Hours	Experiment
1	Derivation of Bernoulli equation with losses.	2	Verification of Bernoulli's theorem
2	Flow through pipes: Laminar and turbulent flow, friction factor	2	Determination of Darcy's coefficient and Chezy's constant
3	Flow measurement: Principle and working	2	Coefficient of discharge for Venturi meter, Orifice meter
4	Flow measurement: Principle and working	2	Calibration of Venturi meter, Orifice meter
5	Flow through packed beds: Ergun equation	2	Determination of Pressure drop for flow through packed bed
6	Fluidization	2	Determination of minimum fluidization velocity and pressure drop profile
7	Flow measurement: Principle and working	2	Hydraulic coefficients of Orifice meter
8	Centrifugal pumps	2	Determination of Efficiency of a Centrifugal Pump
9	Fluid transportation	2	Characteristic study of single end suction pump
10	Flow measurement using Pitot tube	2	Coefficient of discharge for Pitot tube
11	Flow through open channels	2	Determination of coefficient of discharge for different types of weirs

12	Agitation and mixing: power consumption, mixing times, scale up.	2	Determination of Fluid Power Number
13	Pipe fittings, Flow control devices, Pressure and vacuum gauges	4	Study on: Pipe fittings Valves Plumber's tools Instruments for hydraulic flow measurements Pressure and vacuum gauges

CO Assessment Questions	
1	i) Determine the distance between the mercury levels (H) in the U-tube manometer connected to a horizontal pipe transporting oil as shown in figure. The pressure at point X in the pipe is 7 kPa and the specific gravity of oil and mercury are 0.9 and 13.6 respectively.  ii) A solid cylinder 2 m in diameter and 2 m high is floating in water with its axis vertical. If the specific gravity of the material of cylinder is 0.65 find its metacentric height. State whether the equilibrium is stable or unstable.
2	A reducing elbow located in a horizontal plane (gravitational effects are unimportant), through which a liquid of constant density is flowing. The flexible connections, which do not exert any forces on the elbow, serve only to delineate the system that is to be considered; they would not be used in practice, because the retaining forces Fx and Fy would be provided by the walls of the pipe. Neglecting frictional losses, derive expressions for the following, in terms of any or all of the known inlet gauge pressure p1, inlet velocity u1, inlet and exit diameters D1 and D2 (and hence the corresponding cross-sectional areas A1 and A2), and liquid density ρ: (a) The exit velocity u_2 and pressure p_2. (b) The retaining forces Fx and Fy needed to hold the elbow in position. Calculate the two forces Fx and Fy if D_1 = 0.20 m, D_2 = 0.15 m, p1 = 1.5

	bar (gauge), u1 = 5.0 m/s, and ρ = 1,000 kg/m³ (the liquid is water). 
3	i) Water is pumped from a reservoir to a height of 1000 m from the reservoir level, through a pipe of 15 cm I.D. at an average velocity of 4 m/s. If the pipeline along with the fittings is equivalent to 2000 m long and the overall efficiency is 70 %, Calculate the energy required for pumping. Friction factor f is given by $f = 0.046R^{-0.2}$. Derive the Hagen Poiseuille equation starting from the basics.
4	ii) Calculate the flow rate of water (in liters per minute) required to fluidize a bed of 0.0625 m diameter lead shot (SG = 11.3). The bed is 0.3048 m diameter, 1 ft deep, and has a porosity of 0.18. Determine the water flow rate required to sweep the bed away. Design an experiment to estimate the minimum fluidization velocity and entrainment velocity of particle in a given fluidized bed system.
5	i) A horizontal venturi meter with inlet diameter 150 mm and throat diameter 75 mm is used to measure discharge. The differential manometer gives a reading of 150 mm of mercury. Determine the rate of flow if Cd is 0.98. ii) Design an experiment to estimate the venturi/ orifice discharge coefficient for a given flow rate.

24CHJ404	HEAT TRANSFER OPERATIONS	L	T	P	J	S	C	Year of Introduction
		2	0	2	2	5	5	2024

Preamble: The objective of the course is to familiarize the various steady and unsteady state conduction heat transfer situations. This course provides an overall idea of convective heat transfer coefficient, laws of radiation, radiative heat flux and heat transfer mechanism with phase change like boiling and condensation. The knowledge of various heat transfer mechanisms which are taught in this course is useful in the design and analysis of various heat transfer equipments like heat exchangers and evaporators.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to:

CO1	Identify and distinguish various modes of heat transfer and examine the mechanisms involved
CO2	Apply appropriate governing equations and analyse conduction heat transfer problems for different geometries under steady state and transient processes
CO3	Solve forced and natural convection heat transfer problems using empirical equation
CO4	Explain the concepts behind radiation heat transfer and solve radiation heat transfer problems
CO5	Analyze the heat transfer processes involved in boiling and condensation
CO6	Design of heat exchangers and evaporators after interpreting the basic concepts

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3											
CO2	3	3		2								
CO3	3	3		2								
CO4	3	3		2								
CO5	3	3										
CO6	3	3	3		2							

Assessment Pattern for Theory component

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Assessment Pattern for Lab component		
Bloom's Category	**Continuous Assessment Tools**	
	Class work	**Test1**
Remember		
Understand	✔	✔
Apply	✔	✔
Analyse	✔	✔
Evaluate	✔	
Create	✔	

Assessment Pattern for Project component			
Bloom's Category	**Continuous Assessment Tools**		
	Evaluation 1	**Evaluation 2**	**Report**
Remember			
Understand	✔	✔	
Apply	✔	✔	
Analyse	✔	✔	
Evaluate		✔	
Create		✔	

Mark Distribution of CIA								
Course Structure [L-T-P-J]	**Attendance**	**Theory [L- T]**		**Practical [P]**	**Project [J]**			**Total Marks**
		Assignment	**Test-2**	**Class work**	**Evaluation 1**	**Evaluation 2**	**Report**	
2-0-2-2	5	10	10	15	5	10	5	60

Total Marks distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	60	40	2.5 Hrs

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 2		2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x 8 = 40	40

		marks) Time: 2.5 hours	
	Total Marks: 0	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Conduction

Basic Concepts - Overview of applications of heat transfer in different fields of engineering, modes of heat transfer - conduction, convection and radiation, heat transfer with and without change of phase, material properties of importance in heat transfer - thermal conductivity, specific heat capacity, isotropic and anisotropic materials.

Conduction Heat Transfer - General heat conduction equation in cartesian coordinates

Formulation of heat transfer problems with and without generation of heat (uniform and non- uniform heat generation), one dimensional steady state heat conduction without generation of heat: Fourier heat conduction equation,

thermal conductivity of solids, liquids and gases- comparison between them, effect of temperature on thermal conductivity, thermal diffusivity, conduction through systems of constant thermal conductivity - conduction through plane, cylindrical and spherical wall, numerical problems of practical importance based on the above topics.

Thermal insulation - Analysis of Critical radius of insulation for cylinders, optimum thickness of insulation, concept of optimum thickness of insulation, numerical problems based on the above aspects.

MODULE II: Convection

Unsteady State heat Conduction - Analysis of transient heat flow with negligible internal resistance-lumped capacity analysis, concept of Biot Modulus and Fourier number, Numerical problems of practical importance. Convection - Mechanism, boundary layer concepts, thermal and velocity boundary layers, boundary layer thickness, relationship between hydrodynamic and thermal boundary layer thickness for flow over flat plates, the convective heat transfer coefficient, reference temperatures, thermal boundary layers for the cases of flow over a flat plate. Dimensionless numbers in convective heat transfer and their significance. Dimensional analysis Buckingham's pi theorem, its limitations, application of dimensional analysis to forced convection. Forced Convection - General methods for estimation of convection heat transfer coefficient, correlation equations for heat transfer in laminar and turbulent flow for external and internal flows for constant heat flux and wall temperature conditions. flow over flat plates, numerical problems of practical interest. Natural Convection - Dimensional analysis, natural convection from vertical and horizontal surfaces under laminar and turbulent conditions for plates under constant heat flux and wall temperature conditions, physical significance of Grashof and Rayleigh numbers, numerical problems of practical interest. Analogy between momentum and heat transfer- Reynold's analogy.
MODULE III: Radiation, Boiling and Condensation
Heat transfer by radiation: Introduction- theories of radiation, electromagnetic spectrum, thermal radiation, spectral emissive power, surface emission, total emissive power, emissivity, radiative properties- Emission, irradiation, radiosity, absorptivity, reflectivity and transmissivity, concept of black and gray body, radiation intensity, laws of black body radiation, non-black surfaces, gray, white and real surface, radiation between black surfaces and gray surfaces, , radiation shields. Boiling and Condensation - Dimensionless parameters in boiling and condensation, pool boiling, boiling curve, hysteresis in the boiling curve, mechanism of nucleate boiling, modes of pool boiling. condensation - physical mechanisms, types of condensation, factors affecting condensation, laminar film condensation on a vertical plate - detailed analysis by Nusselt to determine the heat transfer coefficient, drop wise condensation, comparison between dropwise and film type condensation, promoters and inhibitors used in condensation.
MODULE IV: Heat Exchangers Classification of Shell and tube heat exchangers - according to flow arrangements - single- pass exchangers, multi-pass exchangers, classification according to heat transfer mechanisms, basic construction of a shell and tube heat exchanger with details of the various parts, Concept of overall heat transfer coefficient - derivation of expression for

overall heat transfer coefficient, Concept and types of fouling - fouling factors, determination of overall heat transfer coefficient with and without fouling, derivation of expression for LMTD, concept of logarithmic mean temperature difference and its correction factor, heat exchanger analysis using LMTD method in parallel flow, counter flow exchanger, cross flow and multi- pass heat exchangers, temperature – distance plots for different flow arrangements in single and multi-pass heat exchangers, NTU, determination of area, length, number of tubes required for a given duty in different configurations using LMTD and NTU method of analysis.
MODULE V: Evaporators
Evaporation - Principle of evaporation, types of evaporators-their construction and operation- short tube vertical or calandria type evaporators, single effect and multiple effect evaporators, performance of evaporators, capacity and economy of evaporators, factors affecting the performance of evaporators, overall heat transfer coefficient, effect of liquid head and boiling point elevation, material and energy balances for single effect evaporator and the calculations on single effect evaporator, numerical problems of practical interest, temperature profile in evaporators. Multiple effect evaporators – Material and energy balance, Different feeding arrangements in multiple feed evaporators
Text books 1. Datta B.K., Heat Transfer: Principles and Applications, Prentice Hall India. 2. McCabe W.L., Smith J.C. & Harriott P., Unit Operations in Chemical Engineering, McGraw Hill. 3. Hollman J.P., Heat Transfer, McGraw Hill. 4. R C Sachdeva, Fundamentals of Engineering Heat and Mass Transfer, New age International Publishers. 5. M.Necati. Ozizik, Heat transfer - A basic Approach, McGraw-Hill College. 6. Coulson J.M. & Richardson J.F., Chemical Engineering, Vol. I and II, ELBS, Pergamon Press. 7. Kern D.Q., Process Heat Transfer, McGraw Hill. 8. Geankopolis C J, Transport Processes and Separation Process Principles, Prentice Hall of India, 4th Edition, Eastern Economy Edition (2004). 9. Incropera F P and DeWitt D P, Introduction to Heat Transfer, 2nd Ed John Wiley New York (1996). 10. Welty J.R., Engineering Heat Transfer, John Wiley

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1	
1.1	Basic Concepts - Overview of applications of heat transfer in different fields of engineering, modes of heat transfer - conduction, convection and radiation.	1

1.2	Heat transfer with and without change of phase, material properties of importance in heat transfer - thermal conductivity, specific heat capacity, isotropic and anisotropic materials.	1
1.3	Conduction Heat Transfer - General heat conduction equation in cartesian coordinates (derivation required).	1
1.4	Formulation of heat transfer problems with and without generation of heat (uniform and non- uniform heat generation), one dimensional steady state heat conduction without generation of heat: Fourier heat conduction equation,	1
1.5	Thermal conductivity of solids, liquids and gases-comparison between them, effect of temperature on thermal conductivity, thermal diffusivity. Conduction through systems of constant thermal conductivity - conduction through plane,	1
1.6	Cylindrical and spherical wall, numerical problems of practical importance based on the above topics. Thermal insulation - Analysis of Critical radius of insulation for cylinders, optimum thickness of insulation, concept of optimum thickness of insulation, numerical problems based on the above aspects.	1
MODULE II		
2.1	Unsteady State heat Conduction - Analysis of transient heat flow with negligible internal resistance-lumped capacity analysis.	1
2.2	Concept of Biot Modulus and Fourier number, Numerical problems of practical importance.	1
2.3	Convection - Mechanism, boundary layer concepts, thermal and velocity boundary layers, boundary layer thickness,	1
2.4	Relationship between hydrodynamic and thermal boundary layer thickness for flow over flat plates, the convective heat transfer coefficient, reference temperatures, thermal boundary layers for the cases of flow over a flat plate. Dimensionless numbers in convective heat transfer and their significance. Dimensional analysis Buckingham's pi theorem, its limitations, application of dimensional analysis to forced convection	1
2.5	Forced Convection - General methods for estimation of convection heat transfer coefficient, correlation equations for heat transfer in laminar and turbulent flow for external and internal flows for constant heat flux and wall temperature conditions. Flow over flat plates, numerical problems of practical interest	1

2.6	Natural Convection - Dimensional analysis, natural convection from vertical and horizontal surfaces under laminar and turbulent conditions for plates under constant heat flux and wall temperature conditions, physical significance of Grashof and Rayleigh numbers, numerical problems of practical interest. Analogy between momentum and heat transfer- Reynolds's analogy.	1
	MODULE III	
3.1	Heat transfer by radiation: Introduction- theories of radiation, electromagnetic spectrum, thermal radiation,	1
3.2	Spectral emissive power, surface emission, total emissive power, emissivity, radiative properties- Emission, irradiation, radiosity, absorptivity, reflectivity and transmissivity, concept of black and gray body, radiation intensity	1
3.3	Laws of black body radiation, non-black surfaces, gray, white and real surface, radiation between black surfaces and gray surfaces, radiation shields.	1
3.4	Boiling and Condensation - Dimensionless parameters in boiling and condensation, pool boiling, boiling curve, Hysteresis in the boiling curve, mechanism of nucleate boiling, modes of pool boiling	1
3.5	Condensation - physical mechanisms, types of condensation, factors affecting condensation, Laminar film condensation on a vertical plate - detailed analysis by Nusselt to determine the heat transfer coefficient, Drop wise condensation, comparison between dropwise and film type condensation, promoters and inhibitors used in condensation	1
	MODULE IV	
4.1	Classification of Shell and tube heat exchangers - according to flow arrangements - single-pass exchangers, multi-pass exchangers, classification according to heat transfer mechanisms	1
4.2	Basic construction of a shell and tube heat exchanger with details of the various parts, Concept of overall heat transfer coefficient - derivation of expression for overall heat transfer coefficient.	1
4.3	Concept and types of fouling - fouling factors, determination of overall heat transfer coefficient with and without fouling, derivation of expression for LMTD, concept of logarithmic mean temperature difference and its correction factor,	1

4.4	Heat exchanger analysis using LMTD method in parallel flow, counter flow exchanger, cross flow and multi-pass heat exchangers, temperature – distance plots for different flow arrangements in single and multi-pass heat exchangers, NTU, determination of area, length, number of tubes required for a given duty in different configurations using LMTD and NTU method of analysis	1
	MODULE V	
5.1	Evaporation - Principle of evaporation, types of evaporators-their construction and operation - short tube vertical or calandria type evaporators, single effect and multiple effect evaporators	1
5.2	Performance of evaporators, capacity and economy of evaporators, factors affecting the performance of evaporators, overall heat transfer coefficient	1
5.3	Effect of liquid head and boiling point elevation, material and energy balances for single effect evaporator and the calculations on single effect evaporator, Numerical problems of practical interest, temperature profile in evaporators.	1
	Multiple effect evaporators – Material and energy balance, Different feeding arrangements in multiple feed evaporators	

LAB COMPONENT

Including laboratory experiments in a course is an excellent way to enhance the understanding of various concepts in the syllabus. It provides students with hands-on experience and practical application of the theoretical knowledge they acquire in the classroom. It also fosters critical thinking, problem-solving, and practical skills that are valuable in their academic and professional pursuits. Here are some key points to consider when incorporating laboratory experiments into a course:

Alignment with Course Objectives: Ensure that the laboratory experiments align with the course objectives and learning outcomes. The experiments should reinforce and complement the concepts taught in the classroom.

Relevance: Select experiments that are relevant to the course material and provide real-world examples of the concepts being discussed. This helps students see the practical applications of what they are learning.

Safety: Safety is paramount in a laboratory setting. Make sure that all experiments are conducted in a safe environment, and students are aware of the safety protocols and precautions.

Equipment and Materials: Ensure that the necessary equipment and materials are available and in good working condition. Students should have access to the tools and resources needed to conduct the experiments effectively.

Clear Instructions: Provide clear and detailed instructions for each experiment. This should include the purpose of the experiment, the procedures to be followed, data collection methods, and any specific requirements.

Data Analysis and Interpretation: Include a component for data analysis and interpretation in the laboratory reports. This encourages critical thinking and helps students draw meaningful conclusions from their experiments.

Variety: Offer a variety of experiments that cover different aspects of the course material. This can include quantitative experiments, qualitative observations, and even open-ended, exploratory experiments.

Feedback and Assessment: Develop a system for assessing and providing feedback on students laboratory reports and performance. This assessment should contribute to their overall course grade.

Integration with Theory: Encourage students to connect the results of their experiments with the theoretical concepts discussed in the classroom. This reinforces their understanding and helps bridge the gap between theory and practice.

Practical Skills: Besides reinforcing theoretical knowledge, laboratory experiments should also help students develop practical skills, such as experimental design, data collection, and analysis.

Reflection: Encourage students to reflect on their experiences during the experiments. This can be done through post-lab discussions or written reflections, allowing students to think critically about what they learned.

Flexibility: Be open to adapting the laboratory component as needed. Sometimes, students may discover unexpected results or encounter challenges. This flexibility can turn such situations into valuable learning experiences.

Resources and Support: Provide access to resources, including lab manuals, research papers, and additional readings, to help students delve deeper into the concepts explored in the experiments.

LESSON PLAN FOR LAB COMPONENT

No.	Topic	No. of Hours	Experiment
1	Conduction: Fourier's law	2	Heat transfer through composite walls
2	Thermal insulation	2	Heat transfer through lagged pipe
3	Thermal conductivity of solids	2	Thermal conductivity of metal rod
4	Thermal conductivity of solids	2	Thermal conductivity of Liquid experiment
5	Convection	2	Natural convection experiment
6	Forced Convection	2	Heat transfer through Pin-Fin Apparatus
7	Unsteady state heat conduction	2	Unsteady state experiment
8	Heat transfer by radiation	2	Emissivity measurement
9	Boiling and Condensation	2	Study on Vertical condenser
10	Heat exchanger	2	Parallel flow/Counter flow heat exchanger

COURSE PROJECT

Incorporating a project component in a course complements theoretical learning and laboratory experiments by providing students with the opportunity to synthesize, apply, and deepen their understanding of course concepts. It also encourages critical thinking, problem-solving, and creativity, which are valuable skills for students academic and professional growth. Here are some key points to consider when including a project component in a course to cover the concepts from the syllabus:

Alignment with Course Objectives: Ensure that the project aligns with the course objectives and learning outcomes. The project should provide an opportunity for students to apply the theoretical knowledge they have gained.

Relevance: Select project topics that are directly related to the course material. The project should enable students to explore and apply the concepts covered in the classroom and laboratory sessions.

Project Types: Consider various project types, such as group projects, case studies, or practical applications. The choice of project type should depend on the course goals and the specific concepts being covered.

Clear Guidelines: Provide clear project guidelines and expectations. Include information on project deliverables, deadlines, and assessment criteria to ensure that students understand what is expected of them.

Student Choice: If possible, allow students to choose project topics that align with their interests or career goals. This can increase motivation and engagement.

Resources and Support: Ensure that students have access to the necessary resources, including literature, software, equipment, or guidance from instructors or mentors.

Interdisciplinary Approach: Encourage interdisciplinary projects that draw on concepts from multiple areas of the syllabus. This can promote a holistic understanding of the subject matter.

Peer Collaboration: Encourage collaboration among students for group projects. Teamwork can foster problem-solving skills and diverse perspectives.

Reflection and Presentation: Require students to reflect on their project experiences and present their findings to the class. This promotes critical thinking and communication skills.

Assessment Criteria: Clearly define how the project component will be graded. Assess not only the final product but also the process, research, problem-solving, and communication skills.

Feedback and Revision: Provide feedback on project proposals and guide students in the right direction. Allow them to revise and improve their work based on feedback.

Integration with Theory and Lab: Emphasize the connection between the project and the theoretical and laboratory components of the course. Encourage students to apply what they have learned in these sessions to their projects.

Real-World Applications: Whenever possible, choose projects that have real-world applications. This can help students see the practical relevance of their coursework.

Sample project topics for students to work on:

1	Water flows through a shower head steadily at a rate of 8 Kg/min. the water is heated in an electric water heater from 15 ^{0}C to 45 ^{0}C. In an attempt to conserve energy, it is proposed to pass the drained warm water at a temperature of 38 ^{0}C through a heat exchanger to preheat the incoming cold water, design a heat exchanger that is suitable for this task, and discuss the potential savings in energy and money of your area.
2	Contact a manufacturer of Aluminum heat sinks and obtain their product catalog for cooling electronic components by natural convection and radiation, explain in detail on how select a suitable sink for an electronic component when it its maximum power dissipation and maximum allowable surface temperature are specified.
3	Investigate the thermal properties of different types of clothing materials. Measure how quickly they conduct heat and how well they insulate. Consider the practical implications for personal comfort in different weather conditions.

LESSON PLAN FOR PROJECT COMPONENT

No.	Topic	No. of Class Hours [24]
1	Preliminary Design of the Project	4
2	Zeroth presentation (4th week)	2
3	Project work - First Phase	4
4	Interim Presentation (7th and 8th weeks)	4
5	Project work - Final Phase & Report writing (discussions in class during project hours)	6
6	Final Evaluation and Presentation (11th and 12th weeks)	4

CO Assessment Questions (Sample)	
1	a) Explain in detail the different modes of heat transfer? b) A composite wall of a furnace is made of two materials A and B. The thermal conductivity of A is twice that of B, while the thickness of layer A is half of that of C. If the temperature at the two sides of the wall are 400 and 1200 K respectively, then, determine the temperature drop across the layer of material A? c) Explain the effect of temperature on thermal conductivity by conducting an experiment. Write a note on thermal conductivity of solid, liquid and gas.

2	a) Derive the general conduction equation in Cartesian coordinates? b) A furnace wall is made up of steel plate 10 mm thick (k=15 Kcal / hr m °C) lined on inside with silica bricks 150 mm thick (k= 1.75 kcal/hr moC) and on the outside with magnesia bricks 200 mm thick (k=4.5 kcal/hrmoC). The inside and outside walls are at 650 °C and 125 °C resp. Calculate the resistance of the composite wall and the total heat loss through the wall? c) Differentiate between natural and forced convection. List the examples of these two processes in the Heat transfer operations laboratory d) Explain the concept of boundary layer. e) Calculate the heat transfer coefficient for a fluid flowing through a tube having inside diameter 40 mm at a rate of 5500 kg/h. Assume that the fluid is being heated Properties of the fluid at mean bulk temperature are: μ = 0.004 kg/ms, ρ = 1.07 g/cc, Cp = 2.72 kJ/ kg K, k = 0.256 W/m K.
3	a) Define emissive power. b) State and explain laws of radiation. c) Derive the expression for net radiant energy exchange between two large parallel planes
4	a) How are heat exchangers classified? b) Write down the material and energy balances for a single effect evaporator system. c) A counterflow shell and tube heat exchanger is to be used to cool water from 27 °C to 6 °C using brine entering at -2 °C and leaving at 3 °C. The overall heat transfer coefficient is estimated to be 500 W/m^2 °C. Calculate the heat transfer surface area for a design heat load of 10 kW.
5	Discuss the material and energy balance calculations of a single effect evaporator.

24HUT465	ENTREPRENEURSHIP AND STARTUPS	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: The goals of this course are to inspire students and help them imbibe an entrepreneurial mindset. The students will learn what entrepreneurship is and how it has impacted the world and their country. They will be introduced to key traits and the DNA of an entrepreneur, and be given an opportunity to assess their own strengths and traits that are needed to become a successful entrepreneur. The course comprises of five modules, each focusing on a specific entrepreneurial knowledge or skill requirement such as creative thinking, communication, risk-taking, and resilience.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Develop awareness about entrepreneurship and successful entrepreneurs.
CO2	Develop an entrepreneurial mindset by performing market research and evaluating opportunities
CO3	List the legal issues associated with start-ups
CO4	Describe the financial sources required to fund startups
CO5	Describe growth stages in new ventures and reasons for scaling ventures.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3									2		2
CO2	3									3		2
CO3	3					3				2		2
CO4	3									2	3	2
CO5	3								3	2	3	2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	□	□	□	□
Understand	□	□	□	□
Apply	□	□	□	□
Analyse			□	

Evaluate			□	
Create			□	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	**40**

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub-divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	**60**
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Introduction to Entrepreneurship

Meaning and concept of entrepreneurship, the history of entrepreneurship development, Myths about entrepreneurs, entrepreneurship and economic management, the entrepreneurial ecosystem, types of entrepreneurs, Entrepreneurship in India.

MODULE II: Identifying opportunities and Business Plan

The Entrepreneurial process, opportunity identification, Market Research for Entrepreneurship, Evaluating opportunities.

The concept of a business plan, the need of a business plan, contents of a business plan, making the business plan, presenting the business plan.

MODULE III: Start-up Legal issues

The Legal Environment, forms of organization, Approval of new ventures, Taxes and duties payable, intellectual property, franchising.

MODULE IV: Startup Financial issues

Types of finance, estimating capital cost of project, securing finance, Sources of finance, What Lenders and investors look for?

MODULE V: Starting up- The Human angle, Venture Survival and Growth

Individual or Team Start-up, acquiring influence by networking, leadership, designing the organization, organization culture.

Venture life patterns, start-up phase, early growth, changes in management style and organization design. New venture failures.

Textbooks

1. Anjan Raichaudhuri, Managing New Ventures Concepts and Cases, Prentice Hall International, 2010.

Reference books

1. Kathleen R Allen, Launching New Ventures, An Entrepreneurial Approach, Cengage Learning, 2016.
2. S. R. Bhowmik & M. Bhowmik, Entrepreneurship, New Age International 2007.
3. Steven Fisher, Ja-nae’ Duane, The Startup Equation -A Visual Guidebook for Building Your Startup, Indian Edition, Mc Graw Hill Education India Pvt. Ltd, 2016.
4. Donald F Kuratko, Jeffrey S. Hornsby, New Venture Management: The Entrepreneur’s Road Map, 2e, Routledge, 2017.
5. Vijay Sathe, Corporate Entrepreneurship, 1e, Cambridge, 2009

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE 1 (6 hours)		
1.1	Meaning and concept of entrepreneurship, the history of entrepreneurship development.	1
1.2	Myths about entrepreneurs, entrepreneurship and economic management.	1
1.3	Myths about entrepreneurs, entrepreneurship and economic management.	1
1.4	The entrepreneurial ecosystem, types of entrepreneurs.	1
1.5	the entrepreneurial ecosystem, types of entrepreneurs.	1
1.6	Entrepreneurship in India.	1
MODULE II (7 hours)		
2.1	The Entrepreneurial process, opportunity identification.	1
2.2	Market Research for Entrepreneurship, Evaluating opportunities.	1
2.3	Market Research for Entrepreneurship, Evaluating opportunities	1
2.4	The concept of a business plan, the need of a business plan.	1
2.5	Contents of a business plan.	1
2.6	Making the business plan, presenting the business plan.	1
2.7	Making the business plan, presenting the business plan.	1
MODULE III (7 hours)		
3.1	The Legal Environment.	1
3.2	Forms of organization.	1
3.3	Approval of new ventures.	1
3.4	Taxes and duties payable.	1
3.5	Taxes and duties payable.	1
3.6	intellectual property, franchising.	1

3.7	Taxes and duties payable.	1
	MODULE IV (7 hours)	
4.1	Types of finance.	1
4.2	Estimating capital cost of project.	1
4.3	Estimating capital cost of project.	1
4.4	Securing finance.	1
4.5	Sources of finance.	1
4.6	Sources of finance.	1
4.7	What Lenders and investors look for?	1
	MODULE V (7 hours)	
5.1	Individual or Team Start-up.	1
5.2	Acquiring influence by networking.	1
5.3	Leadership, designing the organization, organization culture.	1
5.4	Leadership, designing the organization, organization culture.	1
5.5	Venture life patterns, start-up phase.	1
5.6	Early growth, changes in management style and organization design.	1
5.7	New venture failures.	1

	CO Assessment Sample Questions
1	Describe the role of entrepreneurship in a developing economy.
2	You are an entrepreneur who wish to start a new venture in the State of Kerala. Describe the methods to perform market research to identify opportunities. List the entrepreneurial traits and disciplines that are necessary to become a successful entrepreneur.
3	List the taxes and duties payable while starting up a new venture.
4	Explain the role of microfinance institutions in financing entrepreneurs.
5	List the unique funding issues associated with high-tech ventures.

24MCT406	Environmental Sciences	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	0	2024

Preamble: Environmental Sciences is a specialized course designed to provide engineering students with a solid foundation in environmental principles and their application to engineering practice. The course aims to enhance students' understanding of the environmental challenges associated with engineering activities and equip them with the knowledge and skills to integrate environmental considerations into their future engineering work.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Identify ecosystem components and threats.
CO 2	Describe the air and noise pollution problems and their sustainable solutions.
CO 3	Discuss the water and wastewater qualities and its treatment.
CO 4	Explain the various types of solid waste and its management strategies.
CO 5	Associate causes and effects of climate change and suggest climate actions.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	1	3					1			2		1
CO 2	3					2	1					
CO 3	3					2	1					
CO 4	3					2	1					
CO 5	3	3		2		3	2			2		2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	√	√	√	√
Understand	√	√	√	√

Apply	√	√	√	√
Analyse			√	
Evaluate			√	
Create				

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks. Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Environment and Ecosystem

Introduction- Definition and scope of environmental science - Interdisciplinary nature of the field.

Ecosystem structure and function- Biodiversity and its importance - Threats to biodiversity (habitat loss, invasive species, overexploitation) - Man and Environment – Health and Environment – Environmental Ethics.

Sustainable development – Social, economic and environmental dimensions- Need

for Sustainable development, Sustainable Development Goals (SDGs).
MODULE II: Air and Noise pollution
Air pollutants – classification, sources and impacts - Clean air act and national ambient air quality standards (NAAQS) - Air quality index - Emission reduction strategies - Understanding and controlling indoor air pollution. Ground level ozone and photochemical smog - Ozone layer depletion and the Montreal Protocol, Global warming. Noise Pollution: Sources and effects of noise; quantification of noise pollution (Leq, LAeq, etc.); Control and regulation rules in India.
MODULE III: Water and Wastewater
Sources and availability of freshwater- Water conservation strategies - Water pollution and its impacts – Water Quality Standards (IS 10500) - Water quality index; Overview of water treatment plant- Sustainable water use and conflicts over water resources. Wastewater sources and quality –wastewater disposal – Oxygen sag curve - Applicable wastewater discharge standards and typical flow schemes for sewage treatment plant – Decentralized wastewater treatment- natural methods of wastewater treatment.
MODULE IV: Solid and Hazardous Waste Management
Waste Management: Consumerism and our throw-away culture; Characteristics of municipal solid waste; CPHEEO guidelines for solid waste management (overview only); Waste disposal methods (landfill, incineration, recycling). Sustainable practices in waste management - Transition to zero waste lifestyle – Circular Economy. Hazardous and e-waste identification and management - Recycling and waste-to-energy technologies – regulations for hazardous waste management in India (overview only); Biomedical waste and its management.
MODULE V: Climate Action

Climate Change: Evidence, causes and effects, Carbon footprint, Global warming potential; Role of IPCC in the understanding of climate change; Global climate agreements – The United Nations Framework Convention on Climate Change, the Kyoto Protocol, and the Paris Agreement.

Mitigation strategies – carbon capture, utilization, and storage; adapting to climate change.

Renewable Energy- solar energy, Biomass, Wind energy, New Energy sources.

Text books

1. Gilbert M. Masters, Wendell P. Ela, Introduction to Environmental Engineering and Science, 3rd Edition (2013), Pearson Education.
2. Mark Brusseau, Ian Pepper, Charles Gerba, Environmental and Pollution Science, 3rd Edition (2019), Elsevier.
3. Mackenzie L Davis, Introduction to Environmental Engineering, 5th Edition (2012), McGraw hill Education (India).

Reference books

1. Robert A Corbett, Standard Handbook of Environmental Engineering, 2nd Edition (1999), McGraw Hill.
2. B.C Punmia, Wastewater Engineering, 2nd edition (1998), Laxmi Publications Pvt. Ltd.
3. Mackenzie Davis and Susan Masten, Principles of Environmental Engineering & Science, 4th Edition (2004), McGraw Hill.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1 (5 hours)	
1.1	Introduction- Definition and scope of environmental science - Interdisciplinary nature of the field.	1
1.2	Ecosystem structure and function- Biodiversity and its importance.	1
1.3	Threats to biodiversity (habitat loss, invasive species, overexploitation).	1
1.4	Man and Environment – Health and Environment – Environmental Ethics.	1

1.5	Sustainable development – Social, economic and environmental dimensions – Need for Sustainable development, Sustainable Development Goals (SDGs).	1
MODULE II (7 hours)		
2.1	Air pollutants – classification, sources and impacts -	1
2.2	Clean air act and national ambient air quality standards (NAAQS) - Air quality index.	1
2.3	Emission reduction strategies - Understanding and improving indoor air quality.	1
2.4	Ground level ozone and photochemical smog.	1
2.5	Ozone layer depletion and the Montreal Protocol, Global warming.	1
2.6	Noise Pollution: Sources and effects of noise; quantification of noise pollution (Leq, LAeq, etc.).	1
2.7	Control and regulation rules in India.	1
MODULE III (9 hours)		
3.1	Sources and availability of freshwater- Water conservation strategies.	1
3.2	Water pollution and its impacts – Water Quality Standards (IS 10500).	1
3.3	Water quality index; Overview of water treatment plant.	1
3.4	Sustainable water use and conflicts over water resources.	1
3.5	Wastewater sources and quality.	1
3.6	Wastewater disposal – Oxygen sag curve.	1
3.7	Applicable wastewater discharge standards and typical flow	1

	schemes for sewage treatment plant.	
3.8	Decentralized wastewater treatment.	1
3.9	Natural methods of wastewater treatment.	1
MODULE IV (7 hours)		
4.1	Waste Management: Consumerism and our throw-away culture.	1
4.2	Characteristics of municipal solid waste; CPHEEO guidelines for solid waste management (overview only).	1
4.3	Waste disposal methods (landfill, incineration, recycling).	1
4.4	Sustainable practices in waste management - Transition to zero waste lifestyle – Circular Economy.	1
4.5	Hazardous and e-waste identification and management – Recycling.	1
4.6	Waste-to-energy technologies – regulations for hazardous waste management in India (overview only).	1
4.7	Biomedical waste and its management.	1
MODULE V (8 hours)		
5.1	Climate Change: Evidence, causes and effects, Carbon footprint, Global warming potential.	1
5.2	Role of IPCC in the understanding of climate change.	1
5.3	Global climate agreements – The United Nations Framework Convention on Climate Change, the Kyoto Protocol, and the Paris Agreement.	1
5.4	Mitigationstrategies– carbon capture, utilization and storage.	1
5.5	Adapting to climate change.	1
5.6	Renewable Energy- Solar energy.	1

5.7	Biomass, Wind energy.	1
5.8	New Energy sources.	1

CO Assessment Questions	
1	a) Visit any wetland ecosystem and identify the major threats faced. b) How can mangroves aid in coastal protection?
2	a) What are the sources and effects of CO pollution? b) What are the main factors in indoor air quality? c) Explain the impacts of global warming. d) Discuss the control measures for noise pollution.
3	a) List and explain any three water conservation strategies b) Describe the impacts of wastewater discharge to inland water bodies. c) With a neat layout, explain the treatment units in a conventional water treatment plant. d) Write short note on natural methods for wastewater treatment.
4	a) Explain the concept of circular economy. How does it help in achieving zero waste? b) Discuss the management strategies for biomedical waste. c) Classify solid waste based on source. d) Write a short note on Landfills. e) Discuss the e-waste management regulations in India.
5	a) Estimate the carbon footprint of a brick kiln and suggest appropriate climate action. b) Suggest appropriate mitigation strategies for pollution from transportation sector.

24CHT407	Piping and Instrumentation Fundamentals	L	T	P	J	S	C	Year of Introduction
		2	0	0	0	2	2	2024

Preamble:
This course aims to impart the fundamentals of piping. It covers the basic terminologies, codes and standards, and materials used for piping, that any engineer working in a process plant needs to deal with. Another area of focus is to prepare the students to develop P& ID diagrams.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to:

CO1	Explain the materials, dimensions, codes, and standards used in piping.
CO2	Identify the components of a piping system and select the suitable fittings/valves/pumps for a given application.
CO3	Interpret common symbols and abbreviations used in piping and instrumentation diagrams (P&IDs).
CO4	Analyze P&IDs to determine the interconnections between process equipment, instruments, and control systems.
CO5	Describe the different types of instrumentation used in industrial processes and their applications.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2						2				2
CO2	2	2										2
CO3	2	2								2		2
CO4	2	2								2		2
CO5	2											2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	
Understand	✔	✔	✔	
Apply	✔	✔	✔	
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
2-0-0-0	5	35	30	30	100

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	100	-	-

SYLLABUS

MODULE I: Introduction to Piping

Classification of pipes, pipe materials, pipe sizing, pipe wall thickness, schedule number, codes, and standards. Piping colour codes as per types of fluid passing through pipes.

MODULE II: Piping components

Pipe fittings: Functions and properties, types of pipe fittings, and their selection. Gaskets: Functions and properties, types of gaskets, and their selection. Valves: Types of valves, selection criteria of valves for various systems.

MODULE III: Piping and Instrumentation Diagrams (P&IDs)

Purpose and importance of P&IDs in process industries; Interpretation of symbols, abbreviations, and conventions used in P&IDs; Identification and explanation of process lines, equipment, and instrumentation symbols; Introduction to flow diagrams and their representation in P&IDs.

MODULE IV: Piping and Instrumentation Diagram Development

Developing P&IDs for process systems; P&ID development guidelines and best practices; Identification and inclusion of equipment, piping, instrumentation, and control components in P&IDs; Creation of legends, tags, and identifiers in P&IDs.

MODULE V: Instrumentation and Control Devices

Overview of instrumentation and control devices used in process industries; principles of measurement, including pressure, temperature, level, and flow; Instrumentation symbols and their representation in P&IDs; Case studies on instrumentation and control device selection and application.

Textbooks

1. Moe Toghraei - Piping and Instrumentation Diagram Development-Wiley-AIChE (2019)
2. Roger Hunt and Ed Bausbacher, "Process Plant Layout and Piping Design" PTR Prentice-Hall Inc.

Reference books

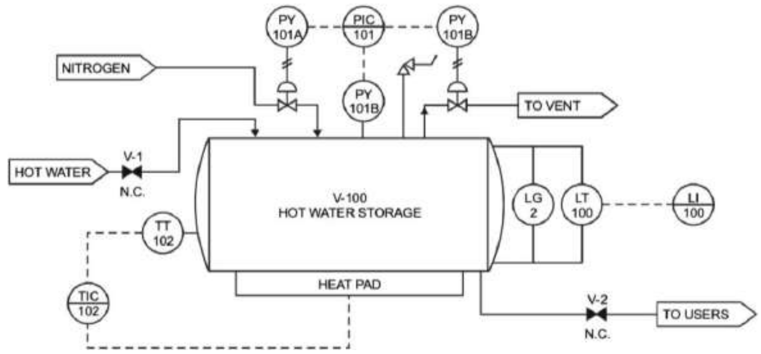
1. Davidson, P.J & West, T. F." Services for the Chemical Industry", Pergamon Press, Oxford,1968.
2. Henry Liu, "Pipeline Engineering", Lewis Publishers.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE 1 (4 Hours)		
1.1	Introduction and Classification of Pipes	01
1.2	Pipe Materials, Sizing, and Wall Thickness	01
1.3	Codes, Standards, and Quality Assurance	01
1.4	Piping Color Codes and Fluid Identification	01
MODULE II (6 Hours)		
2.1	Pipe Fittings - Functions, Properties, and Types	01
2.2	Pipe Fittings - Selection and Installation	01
2.3	Gaskets - Functions, Properties, and Types	01
2.4	Gaskets - Selection and Installation	01
2.5	Valves - Introduction and Types	01
2.6	Valves - Selection and Criteria	01
MODULE III (6 Hours)		
3.1	Introduction to P&IDs and Their Importance	01
3.2	Interpretation of Symbols, Abbreviations, and Conventions	01
3.3	Identification and Explanation of Symbols for Process Lines, Equipment, and Instrumentation	01
3.4	Identification and Explanation of Symbols for Process Lines, Equipment, and Instrumentation	01
3.5	Introduction to Flow Diagrams and Their Representation in P&IDs	01
3.6	Introduction to Flow Diagrams and Their Representation in P&IDs	01
MODULE IV (4 Hours)		
4.1	P&ID Development Guidelines and Best Practices	01
4.2	Identification and Inclusion of Equipment, Piping, Instrumentation, and Control Components	01
4.3	Identification and Inclusion of Equipment, Piping, Instrumentation, and Control Components	01
4.4	Creation of Legends, Tags, and Identifiers in P&IDs	01
MODULE V (4 Hours)		
5.1	Overview of Instrumentation and Control Devices	01
5.2	Instrumentation Symbols and their representation in P&IDs	01
5.3	Principles of Measurement	01
5.4	Case studies on instrumentation and control device selection and application.	01

CO Assessment – Sample Questions	
1	Explain the purpose and importance of codes and standards in piping design, and provide examples of widely used codes and standards in the industry.
2	Compare and contrast different types of fittings, valves, and pumps, highlighting their advantages and disadvantages in specific applications.

3	Explain the importance of consistent and standardized symbols and abbreviations in P&IDs for effective communication and understanding in the industry.
4	Please refer to the provided P&ID image below.

<table>
<tr>
<td></td>
<td>

a) Based on the P&ID, identify the symbols and abbreviations used to represent various components.
b) Explain the function and purpose of the identified symbols and abbreviations in relation to the overall system depicted in the P&ID.</td>
</tr>
<tr>
<td>5</td>
<td>Describe the working of a venturi meter used in industrial applications with a diagram.</td>
</tr>
</table>

FOURTH SEMESTER
HONOUR

24CHH409	Computational Methods in Chemical Engineering	L	T	P	J	S	C	Year of Introduction
		4	0	0	0	4	4	2024

Preamble: This course introduces different methods to solve the partial differential equations applicable to the various chemical engineering processes. This course builds student's knowledge in Eigen value problems, linear algebra, and differential equations, employing appropriate solution methods and applications from chemical engineering to illustrate the techniques. The course will help the students to gain knowledge in formulating the chemical engineering problems and to suggest the solutions.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Apply infinite dimensional spaces to analyze engineering problems.
CO2	Apply the eigen value problems in different chemical engineering problems.
CO3	Solve the homogenous parabolic, elliptical and hyperbolic PDEs.
CO4	Solve the non-homogenous parabolic, elliptical and hyperbolic PDEs
CO5	Solve ODE/PDE using software packages.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3										
CO2	3	3		1	2							
CO3	3	3			2							
CO4	3	3		1	2							
CO5	3	3		1	2							

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	

4-0-0-0	5	5	10	10	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 hours

End Semester Examination [ESE]: Pattern

PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Introduction to vector space (9 Hours)

Vectors, vector spaces, Metrics, Norms, Inner products, Linear dependence and dimension. Contraction mapping, Gram-Schmidt orthogonalization.

MODULE II: Application of Eigen value and vectors (9 Hours)

Matrix determinants and properties, Eigen values, Eigen vectors, Eigen value problems, Eigenvalue problems in discrete and continuous domain. Application of Eigen value problems: Stability analysis and Bifurcation theory.

MODULE III: Solution of homogenous PDEs (10 Hours)

Special ODEs, Properties of adjoint operators. Partial Differential Equation (PDE): Classification, boundary conditions and principle of linear superposition. Solution of PDE: Separation of variable method, Solution of parabolic, elliptical and hyperbolic PDEs.

MODULE IV: Solution of non-homogeneous PDEs (10 Hours)

Solution of PDEs: Cylindrical coordinate system and Spherical coordinate system. Solution of non-homogenous elliptic and parabolic PDEs by Greens theorem.
Solution of PDEs by similarity and integral method.

MODULE V: Applications in chemical engineering (10 Hours)

Case Study 1: Use of ordinary differential equation to analyze the transient response of a unit process /operation.
Solution of any two methods using software packages -Not included for test /end semester examination.
Case Study 2: One-Dimensional mass balance of a reactor/other suitable problem related to solution of partial differential equation. Solution of any two methods using software packages -Not included for test / end semester examination.

Text books

1. Mathematical Methods in Chemical Engineering by S. Pushpavanam, Prentice Hall of India.
2. Applied Mathematics and Modeling for Chemical Engineers by R. G. Rice & D. D. Do, Wiley.
3. Mathematical Method in Chemical Engineering by A. Varma & M. Morbidelli,
Oxford University Press

Reference books

1. Prof. S.De., Advanced Mathematical techniques in Chemical Engineering, NPTEL course, IIT Kharagpur.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE I	
1.1	Introduction to vector space metric, Norm	1
1.2	Introduction to vector space metric, Norm	1
1.3	Inner product space examples	1
1.4	Onto, into, one to one function, completeness of space	1
1.5	Linear combination of vectors, dependents/independent vectors.	1
1.6	Linear combination of vectors, dependents/independent vectors – Sample problems.	1
1.7	Orthogonal and orthonormal vectors, Gram Schmidt orthogonalization.	1
1.8	Orthogonal and orthonormal vectors, Gram Schmidt orthogonalization – Sample problems.	1
1.9	Contraction mapping: definition and examples.	1
	MODULE II	

2.1	Matrix determinants and properties	1
2.2	Eigen values and Eigen vectors, Eigen value problem: Various theorems	1
2.3	Eigen values and Eigen vectors, Eigen value problem: Sample problems	1
2.4	Solution of a set of algebraic equation	1
2.5	Solution of a set of ordinary differential equation	1
2.6	Application of Eigen value problems: Stability analysis	1
2.7	Application of Eigen value problems: Stability analysis	1
2.8	Application of Eigen value problems: Bifurcation theory	1
2.9	Application of Eigen value problems: Bifurcation theory	1
MODULE III		
3.1	Special ODEs, Properties of adjoint operators	1
3.2	PDEs classification, boundary conditions and principle of superposition	1
3.3	PDEs classification, boundary conditions and principle of superposition	1
3.4	Solution of PDE: Separation of variable method	1
3.5	Solution of PDE: Separation of variable method – Sample problems	1
3.6	Solution of Parabolic homogeneous PDEs	1
3.7	Solution of elliptical homogeneous PDEs	1
3.8	Sample problems – Parabolic and elliptical PDE	1
3.9	Solution of hyperbolic homogeneous PDEs	1
3.10	Sample problem – Hyperbolic PDEs	1
MODULE IV		
4.1	Solution of PDEs: Cylindrical coordinate system	1

4.2	Solution of PDEs: Spherical coordinate system	1
4.3	Sample problems for Cylindrical and Spherical system	1
4.4	Solution of non-homogenous parabolic PDEs by Greens theorem	1
4.5	Solution of non-homogenous elliptic PDEs by Greens theorem	1
4.6	Solution of non-homogenous elliptic PDEs by Greens theorem – Sample problem	1
4.7	Solution of PDEs by similarity method	1
4.8	Solution of PDEs by similarity method - Sample problem	1
4.9	Solution of PDEs by integral method	1
4.10	Solution of PDEs by integral method - Sample problem	1
MODULE V		
5.1	Case Study 1: Use of ordinary differential equation to analyze the transient response of a unit process /operation.	1
5.2	Case Study 1: Use of ordinary differential equation to analyze the transient response of a unit process /operation.	1
5.3	Solution of any two methods using software packages	1
5.4	Solution of any two methods using software packages	1
5.5	Solution of any two methods using software packages	1
5.6	Case Study 2: One-Dimensional mass balance of a reactor/other suitable problem related to solution of partial differential equation	1
5.7	Case Study 2: One-Dimensional mass balance of a reactor/other suitable problem related to solution of partial differential equation	1
5.8	Solution of any two methods using software packages	1
5.9	Solution of any two methods using software packages	1
5.10	Solution of any two methods using software packages	1

CO assessment sample questions	
1	Calculate the matric, norm and inner products of $x = [1\ 2\ 3]$ and $y = [4\ 5\ 6]$.
2	Perform the stability analysis of a CSTR system using eigne values.
3	Solve the unsteady state heat conduction equation $$\frac{\partial T}{\partial t} = \alpha \frac{\partial^2 T}{\partial x^2}$$
	Subjected to the conditions: at $t = 0, T = 0$; at $x = 0, T = 0$; at $x = 1, T = f(x) = 3x$
4	Solve the given non-homogenous PDEs using Greens function. $$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial x^2} + f(x, t)$$ Subjected to the conditions: at $t = 0, u = h$; at $x = 0, u = p$; at $x = 1, u = q$
5	Solve the equation below subject to the initial condition $(x, y, 0) = \sin 2\pi x \sin 2\pi y, 0 \le x, y \le 1$, and the conditions $u(x, y, t) = 0, t > 0$ on the boundaries. $$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}$$ Obtain the solution using an appropriate software tool up to three time level with $h = \frac{1}{3}$ and $\alpha = \frac{1}{8}$

24CHH410	Biomass Conversion and Biorefinery	L	T	P	J	S	C	Year of Introduction
		4	0	0	0	4	4	2024

Preamble: This course will provide an insight to the energy utilization from biomass. This course is focusing on the basics of biomass, various conversion technologies, and the different types of products that can be obtained upon successful conversion.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Explain the scenario of biomass as an energy source in the world.
CO 2	Describe the pretreatment and conversion processes of biomass.
CO 3	Illustrate the processes involved in biofuel production.
CO 4	Explain the significance of hydrogen and related fuels.
CO 5	List the processes involved in integrated biorefining.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	3						2					2
CO 2	3						2					
CO 3	3						2					2
CO 4	3						2					2
CO 5	3						2					2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
4-0-0-0	5	15	10	10	40

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 Hrs

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Introduction

Biomass: Availability and abundance, photosynthesis, composition and energy potential, virgin biomass production and selection, waste biomass (municipal, industrial, agricultural and forestry) availability, abundance and potential biomass as energy resources: dedicated energy crops, annual crops (maize, sorghum sugar beet, hemp), perennial herbaceous crops (sugarcane, switchgrass, miscanthus), short rotation woody crops (poplar, willow), oil crops and their biorefinery potential, microalgae as feedstock for biofuels and biochemical, enhancing biomass properties for biofuels, challenges in conversion.

Biorefinery: Basic concept, types of biorefineries, biorefinery feedstocks and properties, economics

MODULE II: Biomass Pretreatment and Conversion Processes

Biomass Pretreatment: Barriers in lignocellulosic biomass conversion, pretreatment technologies such as acid, alkali, autohydrolysis, hybrid methods, role of pretreatment in the biorefinery concept

Physical and Thermal Conversion Processes: Types, fundamentals, equipments and applications; thermal conversion products, commercial success stories

Microbial Conversion Process: Types, fundamentals, equipments and applications, products, commercial success stories

MODULE III: Biofuels

Biodiesel: Diesel from vegetable oils, microalgae and syngas; transesterification; FT

process, catalysts; biodiesel purification, fuel properties.
Bio-oil and Biochar: Factors affecting bio-oil, biochar production, fuel properties, bio-oil upgradation
Bioethanol and Biobutanol: Corn ethanol, lignocellulosic ethanol, microorganisms for fermentation, current industrial ethanol production technology

MODULE IV: Modern Bio Energy Sources

Hydrogen, Methane and Methanol: Biohydrogen generation, metabolic basics, feedstocks, dark fermentation by strict anaerobes, facultative anaerobes, thermophilic microorganisms, integration of biohydrogen with fuel cell; fundamentals of biogas technology, fermenter designs, biogas purification, methanol production and utilization
Organic Commodity Chemicals from Biomass: Biomass as feedstock for synthetic organic chemicals, lactic acid, polylactic acid, succinic acid, propionic acid, acetic
acid, butyric acid, 1,3-propanediol, 2,3-butanedioil, PHA

MODULE V: Integrated Biorefinery

Integrated Biorefinery: Concept, corn/soybean/sugarcane biorefinery, lignocellulosic biorefinery, aquaculture and algal biorefinery, waste biorefinery, hybrid chemical and biological conversion processes, techno- economic evaluation, life-cycle assessment

Text books

1. A.A. Vertes, N. Qureshi, H.P. Blaschek, H. Yukawa (Eds.), Biomass to Biofuels: Strategies for Global Industries, Wiley, 2010.
2. S. Yang, H.A. El-Enshasy, N. Thongchul (Eds.), Bioprocessing Technologies in Biorefinery for Sustainable Production of Fuels, Chemicals and Polymers, Wiley, 2013.

Reference Books

1. Donald L. Klass, Biomass for Renewable Energy, Fuels, and Chemicals, Academic Press, Elsevier, 2006.
2. Prabir Basu, Biomass Gasification, Pyrolysis and Torrefaction, Academic Press, Elsevier, 2013.
3. Shang-Tian Yang (Ed.), Bioprocessing for Value Added Products from Renewable Resources, Elsevier, 2007.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE 1 (10 hours)		
1.1	Introduction and scope.	1
1.2	World energy scenario, consumption pattern, fossil fuel depletion and environmental issues	1
1.3	Biomass production and selection	1
1.4	Biomass production and selection	1

1.5	Biomass as energy resources: dedicated energy crops- annual crops, perennial herbaceous crops	1
1.6	Short rotation woody crops, oil crops and their biorefinery potential, microalgae as feedstock for biofuels and biochemical	1
1.7	Enhancing biomass properties for biofuels, challenges in conversion	1
1.8	Introduction to Biorefinery	1
1.9	Biorefinery feedstocks and properties, economics	1
1.10	Biorefinery feedstocks and properties, economics	1
MODULE II (10 hours)		
2.1	Biomass Pretreatment	1
2.2	Physical and Thermal Conversion Processes -Types and fundamentals, equipments and applications	1
2.3	Physical and Thermal Conversion Processes -Types and fundamentals, equipments and applications	1
2.4	Physical and Thermal Conversion Processes -Types and fundamentals, equipments and applications	1
2.5	Thermal conversion products, commercial success stories	1
2.6	Thermal conversion products, commercial success stories	
2.7	Microbial Conversion Process Types, fundamentals,	1
2.8	Microbial Conversion Process Types, fundamentals,	1
2.9	Equipments used and applications; commercial success stories	1
2.10	Equipments used and applications; commercial success stories	1
MODULE III (9 hours)		
3.1	Biodiesel Diesel from vegetable oils, microalgae and syngas	1
3.2	Transesterification; FT process, catalysts; biodiesel purification, fuel properties	1
3.3	Bio-oil and Biochar: Factors affecting bio-oil, biochar production	2
3.4	Bio-oil and Biochar: Factors affecting bio-oil, biochar production	
3.5	Fuel properties, bio-oil upgradation	1
3.6	Bioethanol and Biobutanol -Corn ethanol, lignocellulosic ethanol,	1

3.7	Bioethanol and Biobutanol -Corn ethanol, lignocellulosic ethanol,	1
3.8	Microorganisms for fermentation, current industrial ethanol production technology	1
3.9	Microorganisms for fermentation, current industrial ethanol production technology	1
	MODULE IV (8 hours)	
4.1	Hydrogen and Biohydrogen generation	1
4.2	Hydrogen and Biohydrogen generation	1
4.3	integration of biohydrogen with fuel cell	1
4.4	integration of biohydrogen with fuel cell	1
4.5	Methane, Biogas and Methanol	1
4.6	Methane, Biogas and Methanol	1
4.7	Organic Commodity Chemicals from Biomass	1
4.8	Organic Commodity Chemicals from Biomass	1
	MODULE V (8 hours)	
5.1	Integrated Biorefinery: Concept, corn/soybean/sugarcane biorefinery	1
5.2	Integrated Biorefinery: Concept, corn/soybean/sugarcane biorefinery	1
5.3	Lignocellulosic biorefinery, aquaculture, and algal biorefinery, waste biorefinery	1
5.4	Hybrid chemical and biological conversion processes	1
5.5	Techno-economic evaluation	1
5.6	Life-cycle assessment	
5.7	Life-cycle assessment	1
5.8	Life-cycle assessment	

CO Assessment Sample Questions	
1	Explain the energy consumption pattern in India
2	Describe the role of pretreatment in the biorefinery
3	List the factors affecting the bio-oil production
4	Explain the different methods involved in biogas purification

5	Describe the processes in lignocellulosic biorefinery.

		L	T	P	J	S	C	Year of Introduction
24CHH411	**Modern Methods of Instrumentation**	4	0	0	0	4	4	**2024**

Preamble: This course introduces students to some modern ideas and tools used for measuring variables in a process industry which are essential for proper control and functioning of all equipment's and processes. The course covers temperature measurements, pressure measurements, flow measurements, composition analysis using spectroscopic methods and advanced sensors and measurement techniques in Chemical Engineering.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Explain the basic principles of measurement instrumentation and characterize instruments based on their performance characteristics.
CO 2	Explain and sketch various measuring instruments used for temperature measurement and their safe application.
CO 3	Characterize and sketch various measuring instruments used for level and pressure in process industries.
CO 4	Explain measurement instrumentation for flow measuring in various applications.
CO 5	Familiarize modern method of instrumentation for composition analysis, humidity and moisture content measurement and advanced Sensors and measurement techniques in Chemical Engineering

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO 8	PO 9	PO10	PO11	PO12
CO 1	3	2	3									1
CO 2	3		1									1
CO 3	3		1									1
CO 4	3		1									1
CO 5	3		1		2							1

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	**Attendance**	**Theory [L- T]**			**Total Marks**
		Assignment	**Test-1**	**Test-2**	
4-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 hr

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Introduction – Temperature measurements

Introduction-definition of instrumentation-concept of an instrument, basic principles of measurements -Temperature measurements, temperature scales, mercury in glass thermometers, bimetallic thermometers, resistance thermometers, thermocouples, thermistors, Resistance Thermal Detectors (RTD), optical pyrometers, radiation pyrometers, ranges of different types of temperature measuring instruments, sources of errors and precautions to be taken in temperature measurements.

MODULE II: Pressure measurements

Industrial pressure measurement by Bourdon gauge, bellows, diaphragm, electrical pressure transducers, strain gauges and piezoelectric manometers, Pressure measurement of corrosive liquids, Level measurement-direct type and indirect type. Differential pressure method for pressurized vessels, Conductivity meters, Solid level detectors.

MODULE III: Flow measurements

Flow measurements: magnetic flow meters, turbine meters, Ultrasonic Flow Meters, Vortex Flow Meters, measuring flow of dry materials by mass flow meters, Thermal Mass Flow Meters, heat input flow meter, venturimeters, moisture content determination by thermal drying. Instruments for measuring humidity like hygrometer, psychrometer, dew point apparatus.
MODULE IV: Composition Analysis using spectroscopic methods
Introduction to spectroscopic techniques- Electrothermal AAS, Hydride generation AAS and Flameless mercury analysis, Inductively Coupled Plasma Atomic Emission Analysis, Infrared spectrometry, Introduction to X-Ray techniques, XRD, XRF Introduction to NMR spectroscopy and mass spectrometry, Chromatographic analysis: GC, LC, HPLC, Hyphenated techniques.
MODULE V: Advanced Sensors and Measurement Techniques in Chemical Engineering
Electrochemical Sensors - Types of Electrochemical Sensors: Potentiometric, Amperometric, and Conductometric Sensors and their applications - Nanosensors and their Applications in Chemical Engineering. Smart Sensors and Internet of Things (IoT) in Chemical Engineering, Process Analytical Technology (PAT) in Chemical Engineering - Overview of Process Analytical Technology (PAT)
Text books 1. Jain R K, Mechanical and Industrial measurements, Khanna publishers 2. Patranabis D, Principles of Industrial Instrumentation, Tata- McGraw Hill.
Reference books 1. Ernest O Doeblin, Measurement systems, Application and Design, McGraw Hill 2. Donald P Eckman, Industrial Instrumentation, CBS Publishers and Distributors, NewDelhi 3. H.Willard , L.L Meritt, J.A Dean and F.A.Settle : Instrumental Methods of Analysis, 6th Edition, CBS. 2. 4. A.I.Vogel: Quantitative Inorganic Analysis, 5th Edition, ELBS. 4. G.W. Ewing: Analytical Instrumentation Hand book, Marcell Dekker, New York, 1990.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1 (9 hours)	
1.1	Introduction-definition of instrumentation-concept of an instrument	1
1.2	Basic principles of measurements	1
1.3	Temperature measurements, temperature scales	1
1.4	Basic principles and working of thermometers, mercury in glass	1
1.5	Bimetallic thermometers	1
1.6	Thermocouples and thermoelectricity	1
1.7	Thermistors, resistance thermal detectors (RTD), optical pyrometers, radiation pyrometers.	1

1.8	Ranges of different types of temperature measuring instruments, sources of errors and precautions to be taken in temperature measurements	1
1.9	Ranges of different types of temperature measuring instruments, sources of errors and precautions to be taken in temperature measurements	1
MODULE 2 (9 hours)		
2.1	Industrial pressure measurement by Bourdon gauge, bellows diaphragm	1
2.2	Industrial pressure measurement by Bourdon gauge, bellows diaphragm	1
2.3	Pressure measurement by electrical pressure transducers	1
2.4	Strain gauges and piezoelectric manometers	1
2.5	Strain gauges and piezoelectric manometers	1
2.6	Pressure measurement of corrosive liquids	1
2.7	Level measurement-direct type and indirect type	1
2.8	Differential pressure method for pressurized vessels	1
2.9	Conductivity meters. Solid level detectors	1
MODULE III (9 hours)		
3.1	Flow measurements: magnetic flow meters, turbine meters	1
3.2	Flow measurements: magnetic flow meters, turbine meters	1
3.3	Ultrasonic Flow Meters, Vortex Flow Meters	1
3.4	Measuring flow of dry materials by mass flow meters	1
3.5	Thermal Mass Flow Meters,heat input flow meter, venturimeters	1
3.6	Thermal Mass Flow Meters, heat input flow meter, venturimeters	1
3.7	Moisture content determination by thermal drying	1

3.8	Instruments for measuring humidity like hygrometer, psychrometer, dew point apparatus	1
3.9	Instruments for measuring humidity like hygrometer, psychrometer, dew point apparatus	1
MODULE IV (9 hours)		
4.1	Introduction to spectroscopic techniques	1
4.2	Electrothermal AAS	1
4.3	Hydride generation AAS	1
4.4	Flameless mercury analysis	1
4.5	Inductively Coupled Plasma Atomic Emission Analysis.	1
4.6	Infrared spectrometry. Introduction to X-Ray techniques, XRD, XRF	1
4.7	Introduction to NMR spectroscopy and mass spectrometry.	1
4.8	Chromatographic analysis: GC, LC	1
4.9	HPLC, Hyphenated techniques.	1
MODULE V (9 hours)		
5.1	Electrochemical Sensors - Types of Electrochemical Sensors: Potentiometric sensors	1
5.2	Amperometric, and Conductometric Sensors and their applications	1
5.3	Amperometric, and Conductometric Sensors and their applications	1
5.4	Nanosensors and their Applications in Chemical Engineering.	1
5.5	Nanosensors and their Applications in Chemical Engineering	1
5.6	Smart Sensors and Internet of Things (IoT) in Chemical Engineering	1
5.7	Smart Sensors and Internet of Things (IoT) in Chemical Engineering	1
5.8	Process Analytical Technology (PAT) in Chemical Engineering	1
5.9	Overview of Process Analytical Technology (PAT)	1

CO Assessment Sample Questions	
CO1	In the context of measurement instruments, define sensitivity and explain its significance in different applications. Explain, how to optimize the sensitivity of an instrument without sacrificing other performance characteristics.
CO2	In an industrial setting, outline three essential safety measures that should be followed when using temperature measuring instruments. Explain how these measures can help prevent accidents and ensure safe operations during temperature measurements.
CO3	Suggest a method for the measurement of pressure above 10,000kg/cm^2. Write its working principle.
CO4	Compare and contrast magnetic flow meters and ultrasonic flow meters for measuring fluid flow. Explain their working principles and list out the advantages and limitations of each type of flow meter.
CO5	Provide an example of a hyphenated technique and explain how it enhances the analytical capabilities of chromatographic analysis.

FOURTH SEMESTER
MINOR

24CHM409	MECHANICAL UNIT OPERATIONS	L	T	P	J	S	C	Year of Introduction
		4	0	0	0	0	4	2024

Preamble: This course gives an introduction to the fundamental particle processing concepts. Separation of solids and size reduction operation techniques are discussed. Industrially important methods for storage and transportation of particles are familiarized.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Analyze particle size distribution of a given sample and present the result in a useful form
CO2	Infer the fundamental particle processing concepts and unit operations in the industrially important field of mineral beneficiation.
CO3	Examine the fundamental concepts of various methods for handling materials in process industries like screening, classification, sedimentation, filtration, etc.
CO4	Select suitable equipment for handling materials in process industries like screening, classification, sedimentation, filtration etc.
CO5	Select a suitable method for storage and transportation of bulk solids in process industries.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2										1
CO2	2	2										1
CO3	3	2										1
CO4	3	2										1
CO5	3	2										1

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	**Attendance**	**Theory [L- T]**			**Total Marks**
		Assignment	**Test-1**	**Test-2**	
4-0-0-0	5	15	10	10	40

Total Mark distribution

Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 Hours

End Semester Examination [ESE]: Pattern

PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I : Characterization of particles and screening

Particle diameter and shape factor - particle size analysis - sieve analysis - particle size distribution - cumulative and differential methods of analysis - mean diameters – specific surface area and number of particles – screening-effectiveness and capacity of screens and factors affecting them - types of industrial screens.

MODULE II : Size separation and mineral beneficiation techniques

Principles of free and hindered settling - equal settling particles - types of classifiers (limited to construction and working) – gravity settling tank, double cone classifier, rake classifier, principles of mineral beneficiation methods - jigging - froth flotation.

MODULE III : Comminution

Laws of comminution - mechanism and efficiency of size reduction - principles of important size reduction equipments (limited to equipments listed) – Jaw Crusher, Gyratory Crusher, Hammer mills, Ball mills, Fluid-energy mills, closed circuit and
open circuit grinding – free crushing and choke feeding.

MODULE IV : Filtration

Filtration - theory of constant pressure and constant rate filtration - cake porosity
and compressibility - filter aids - types of batch and continuous filters (plate and
frame, rotary, leaf filters-construction and working).

MODULE V : Air separation methods, Storage and transport of solids

Air separation methods - cyclone separation – electrostatic precipitation – Bag filters- venturi scrubber - storage and conveying of solids (numerical problems are not required) - silos, bins and hoppers -different types of conveyors (Belt, chain, screw,
pneumatic) - selection of conveyors.

Text books

1. McCabe W.L., Smith J.C. and Harriot P., Unit Operations of Chemical Engineering, McGraw Hill, New York 2001. 6th Edition
2. Anup K Swain, Hemlata Patra, G.K.Roy, Mechanical Operations, Mc-Graw- Hill 2nd Education

Reference books

1. Coulson J. M. and Richardson J.F; Chemical Engineering Vol. 1& 2 Publishers: Butterworth – Heinemann Ltd. 2001-2002.
2. Christie J. GeanKoplis, Transport processes & Unit Operation Prentice hall International
3. Badger & Banchero, Introduction to Chemical Engineering, Mc-Graw- Hill Education
4. C.M.Narayan,B.C.Bhattacharyya,Mechanical Operations for Chemical Engineers, Khanna publishers.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1 (9 hours)	
1.1	Particle diameter and shape factor	1

1.2	Particle size analysis - sieve analysis - particle size distribution - cumulative and differential methods of analysis	1
1.3	Particle size analysis - sieve analysis - particle size distribution - cumulative and differential methods of analysis	1
1.4	Particle size analysis - sieve analysis - particle size distribution - cumulative and differential methods of analysis	1
1.5	Mean diameters – specific surface area and number of particles	1
1.6	Screening-effectiveness and capacity of screens and factors affecting them -	1
1.7	Screening-effectiveness and capacity of screens and factors affecting them -	1
1.8	Types of industrial screens.	1
1.9	Types of industrial screens.	1
MODULE II (10 hours)		
2.1	Principles of free and hindered settling - equal settling particles	1
2.2	Principles of free and hindered settling - equal settling particles	1
2.3	Principles of free and hindered settling - equal settling particles	1
2.4	Types of classifiers (limited to construction and working) – gravity settling tank, double cone classifier, rake classifier	1
2.5	Types of classifiers (limited to construction and working) – gravity settling tank, double cone classifier, rake classifier	1
2.6	Principles of mineral beneficiation methods - jigging	1
2.7	Principles of mineral beneficiation methods - jigging	1
2.8	Froth flotation	1
2.9	Froth flotation	1
2.10	Froth flotation	1
MODULE III (9 hours)		

3.1	Laws of comminution - mechanism and efficiency of size reduction	1
3.2	Laws of comminution - mechanism and efficiency of size reduction	1
3.3	Laws of comminution - mechanism and efficiency of size reduction	1
3.4	Principles of important size reduction equipments (limited to equipments listed) – Jaw Crusher, Fluid-energy mills.	1
3.5	Principles of important size reduction equipments (limited to equipments listed) – Jaw Crusher, Fluid-energy mills.	1
3.6	Gyratory Crusher	1
3.7	Hammer mills	1
3.8	Ball mills	1
3.9	closed circuit and open circuit grinding – free crushing and choke feeding.	1
MODULE IV (10 hours)		
4.1	Filtration - theory of constant pressure and constant rate filtration -	1
4.2	Filtration - theory of constant pressure and constant rate filtration	1
4.3	Filtration - theory of constant pressure and constant rate filtration	1
4.4	Cake porosity and compressibility	1
4.5	Types of batch and continuous filters -plate and frame	1
4.6	Types of batch and continuous filters -plate and frame	1
4.7	Rotary filter	1
4.8	Leaf filters	1
4.9	Numerical problems to find washing time	1
4.10	Numerical problems to find washing time	1
MODULE V (10 hours)		
5.1	Air separation methods - cyclone separation	1
5.2	Electrostatic precipitation	1
5.3	Bag filters-	1
5.4	Venturi scrubber	1
5.5	Storage and conveying of solids (numerical problems are not required) - silos, bins and hoppers	1

5.6	Storage and conveying of solids (numerical problems are not required) - silos, bins and hoppers	1
5.7	Different types of conveyors (Belt, chain, screw, pneumatic)	1
5.8	Different types of conveyors (Belt, chain, screw, pneumatic)	1
5.9	Selection of conveyors.	1
5.10	Selection of conveyors.	1

CO Assessment Sample Questions	
1	Explain capacity and effectiveness of a screen. Derive an expression to find screen effectiveness.
2	You are a process engineer responsible for separating particles from liquids. Select an equipment that can be used for separating equally falling particles. Describe the principle and working of the equipment with a diagram.
3	Describe the construction and working of a ball mill with a diagram.
4	Describe the construction and working of a rotary drum filter.
5	Describe the working of different types of conveyors use conveyors used in cement industries.

FIFTH SEMESTER

24CHT501	Mass Transfer Operations - I	L	T	P	J	S	C	Year of Introduction
		2	1	0	0	2	3	2024

Preamble: This course gives the fundamentals of mass transfer operations in industrial processes. The content includes the fundamentals on molecular diffusion, Gas-Liquid contacting equipment for separation process and estimation of number of stages in distillation column using suitable numerical solutions applied in the design of industrial separation process.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Determine mass flux and estimate diffusion coefficients in interface mass transfer.
CO2	Select suitable Gas-Liquid contacting equipment for mass transfer operations and identify its operational difficulties.
CO3	Determine operating parameters for gas-liquid absorption in tray and packed columns.
CO4	Estimate the composition of distillate and residue from various binary separation methods.
CO5	Determine the number of stages in a fractionation column using McCabe-Thiele method.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2									2
CO2	3	2	2									2
CO3	3	3	2									2
CO4	3	3	2									2
CO5	3	3	2									2

Assessment Pattern

Bloom's Category	**Continuous Assessment Tools**			**End Semester Examination**
	Test1	**Test 2**	**Other tools**	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
2-1-0-0	5	15	10	10	40

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 Hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Molecular Diffusion and Fundamentals

Molecular diffusion - mass fluxes J_A and N_A - Fick's law - diffusivity and estimation -steady state diffusion of A through stagnant B and equimolar counter diffusion in binary gases, liquids and multi component gas mixtures. Mass transfer coefficients, dimensionless groups - analogy between mass, heat and momentum transfer. Basic concepts and assumptions involved in theories of mass transfer: penetration and surface renewal theories- interphase mass transfer - equilibrium - diffusion between phases - two-film theory – local and overall k-type coefficients.

MODULE II: Gas-Liquid contacting equipments

Gas-Liquid contacting equipments for mass transfer operations - single stage and
multistage contact, tray towers, tray types and general features of tray designs (qualitative treatment), continuous contact equipment, wetted wall columns, venturi scrubbers, packed columns, packing materials and characteristics, general constructional details of packed columns, Factors affecting column performance-flooding, priming, coning, weeping, loading etc., comparison between plate and packed columns.

MODULE III: Gas-Liquid Absorption

Gas absorption - Solubility of gases in liquid, choice of solvent, Material balance in
counter current and co-current absorption and stripping, L/G ratio, Minimum gas liquid ratio, Multistage operation, number of plates by graphical construction,

Kremser equation, tray efficiency, design of packed columns, transfer unit and
general graphical method, dilute solutions and simplified design methods.

MODULE IV: Distillation Fundamentals

Distillation- Vapour-Liquid Equilibria, boiling- point diagram and equilibrium curves,
relative volatility, application of Raoult's law. Distillation methods- flash distillation, Simple distillation or Differential distillation, Binary distillation, Steam distillation, Problems.

MODULE V: Design of Distillation Column

Fractionation of binary mixtures, Principle of fractionation, Fractionation in plate columns, condensers and reboilers. Material and energy balance, Design of fractionation columns by McCabe - Thiele method - basic assumptions, feed quality and feed line, number of plates, feed plate location, total reflux, minimum reflux,
optimum reflux, plate efficiency, cold reflux and open steam.

Text books

1. Treybal R.E., Mass Transfer Operations, McGraw Hill.
2. Binay K Dutta, Principles of Mass Transfer & Separation Processes, PHI Learning Private Limited.

Reference books

1. K.V. Narayanan and B. Lakshmikutty. Mass Transfer-Theory and Applications, CBS Publishers.
2. N. Anantharaman and K.M.Meera Sheriffa Begum, Mass Transfer-Theory and Practice, PHI Learning Private Limited (2011) New Delhi.
3. Welty J.R., Wilson R.E. & Wicks C.E., Fundamentals of Momentum Heat and Mass Transfer, John Wiley
4. Foust A.S. et. al., Principles of Unit Operations, John Wiley
5. McCabe W.L., Smith J.C. & Harriot P., Unit Operations in Chemical Engineering, McGraw Hill.
6. Seader J.D.& Henley E.J Separation Process Principles, John Wiley & Sons
7. Coulson J.M. & Richardson J.F., Chemical Engineering, Vol. II, ELBS, Pergamon.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1 (6 hours)	
1.1	Molecular diffusion - mass fluxes J_A and N_A - Fick's law.	1
1.2	Diffusivity and estimation -steady state diffusion of A through stagnant B and equimolar counter diffusion in binary gases, liquids and multi component gas mixtures.	1
1.3	Mass transfer coefficients, dimensionless groups - analogy between mass, heat and momentum transfer.	1
1.4	Basic concepts and assumptions involved in theories of mass transfer: penetration and surface renewal theories.	1
1.5	interphase mass transfer - equilibrium - diffusion between phases - two-film theory.	1
1.6	Local and overall k-type coefficients.	1
	MODULE II (9 hours)	
2.1	Gas-Liquid contacting equipments for mass transfer operations.	1
2.2	Single stage and multistage contact.	1
2.3	Tray towers, tray types and general features of tray designs (qualitative treatment).	1
2.4	Continuous contact equipments.	1
2.5	wetted wall columns, venturi scrubbers.	1

2.6	Packed columns, packing materials and characteristics.	1
2.7	General constructional details of packed columns.	1
2.8	Factors affecting column performance-flooding, priming, coning, weeping, loading etc.	1
2.9	Comparison between plate and packed columns.	1
MODULE III (6 hours)		
3.1	Distillation- Vapour-Liquid Equilibria.	1
3.2	boiling- point diagram and equilibrium curves.	1
3.3	relative volatility, application of Raoult's law.	1
3.4	Distillation methods- flash distillation.	1
3.5	Simple distillation or Differential distillation/ Binary distillation.	1
3.6	Steam distillation, Problems.	1
MODULE IV (8 hours)		
4.1	Fractionation of binary mixtures, Principle of fractionation.	1
4.2	Fractionation in plate columns.	1
4.3	condensers and reboilers.	1
4.4	Material and energy balance, Design of fractionation columns by McCabe - Thiele method - basic assumptions.	1
4.5	feed quality and feed line.	1
4.6	number of plates, feed plate location.	1
4.7	total reflux, minimum reflux, optimum reflux.	1
4.8	plate efficiency, cold reflux and open steam.	1
MODULE V (7 hours)		
5.1	Gas-Liquid contacting equipments for mass transfer operations - single stage and multistage contact.	1
5.2	Tray towers, tray types and general features of tray designs (qualitative treatment).	1
5.3	Continuous contact equipment, wetted wall columns, venturi scrubbers.	1

5.4	Packed columns, packing materials and characteristics.	1
5.5	General constructional details of packed columns.	1
5.6	Factors affecting column performance-flooding, priming, coning, weeping, loading etc.	1
5.7	Comparison between plate and packed columns.	1

CO Assessment Sample Questions	
1	Ammonia is diffusing through a stagnant gas mixture consisting of 1/3 N_2 and 2/3 H_2 by volume. The total pressure is 206.8 kN/m^2 and temperature 54 °C. Calculate the rate of diffusion of ammonia through a film of gas 0.5 mm thick, when concentration change across the film is 10% to 5% by volume. The diffusivity of ammonia in the gas mixture is 2.45×10^{-5} m^2/s.
2	Solute A is to be absorbed from a gas mixture flowing at a velocity 8 m/s on a wet solid surface immersed in the flowing stream. It is difficult to determine the mass transfer coefficient experimentally. However, heat transfer data for the same geometry under similar flow conditions are available. Heat transfer coefficient is obtained as 6.4 x 10^{-2} kW/m^2K. The heat capacity and density of the gas mixture are 1 kJ/kgK and 1.15 kg/m^2. Calculate the value of k_c for the given process. Given Pr = 0.77 and Sc = 0.59 for the gas mixture.
3	A feed of 65 % (mole) Hexane and 35 % (mole) Octane is fed to a pipe still through a pressure reducing valve into a flash disengaging chamber. The vapour and liquid leaving the chamber are assumed to be in equilibrium. If 60 % (mole) of feed is vaporized, find the composition of the top and bottom products. Equilibrium data are given below.

Mole fraction of Hexane in liquid (x)	1.00	0.69	0.40	0.192	0.045	0.00
Mole fractions of Hexane in vapor (y)	1.00	0.932	0.78	0.538	0.1775	0.00

4	A mixture of benzene and toluene is containing 38 mol % benzene is to be separated to give a product of 90 mol % of benzene at the top, and bottom product with 4 mol % benzene. The feed enters the column at its bubble point and vapour leaving the column is condensed

	and provides product and reflux. It is proposed to operate the unit with reflux ratio of 3.0. Determine the number of theoretical plates and locate the feed plate. The vapour pressures of pure benzene and toluene are 1460 mm Hg and 584 mm Hg respectively. Total pressure is 750 mmHg.
5	Explain with a neat sketch the working of tray tower and problems associated with its working.

24CHJ502	KINETICS AND REACTOR DESIGN	L	T	P	J	S	C	Year of Introduction
		2	0	2	2	5	5	2024

Preamble: The course is designed to provide students with a comprehensive understanding of the fundamental principles and practical aspects governing chemical reactions in engineering processes. Through a combination of theoretical discussions, practical examples, and hands-on exercises, this course aims to equip students with the knowledge and skills necessary to analyze, design, and optimize chemical processes. By the end of the course, students will have a profound appreciation for the intricate mechanisms that govern chemical reactions and their pivotal role in shaping the landscape of modern chemical engineering.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Apply knowledge from stoichiometry, kinetics and reactor design to solve complex engineering problems
CO2	Analyze process reactor data and determine rate law parameters for chemical reactions
CO3	Apply theoretical knowledge from stoichiometry, kinetics and reactor design to real-world scenarios considering economic, safety, ethical and environmental factors.
CO4	Develop optimal operational conditions for ideal reactor with single and multiple reactions
CO5	Apply the thermodynamic principles to understand the no isothermal behaviour of reactions.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	2						3		2
CO2	3	3	2	2								2
CO3	3	3	3	2		3	3	3	3	3		2
CO4	3	3	2									2
CO5	3	3	2									2

Assessment Pattern for Theory component				
Bloom's Category	**Continuous Assessment Tools**			**End Semester Examination**
	Test1	**Test2**	**Other tools**	
Remember		✔	✔	✔
Understand		✔	✔	✔
Apply		✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Assessment Pattern for Lab component		
Bloom's Category	**Continuous Assessment Tools**	
	Class work	**Test1**
Remember		
Understand	✔	✔
Apply	✔	✔
Analyse	✔	✔
Evaluate		
Create		

Assessment Pattern for Project component			
Bloom's Category	**Continuous Assessment Tools**		
	Evaluation 1	**Evaluation 2**	**Report**
Remember			
Understand	✔	✔	
Apply	✔	✔	
Analyse	✔	✔	
Evaluate		✔	
Create		✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	**Attendance**	**Theory [L- T]**		**Practical [P]**	**Project [J]**			**Total Marks**
		Assignment	**Test-2**	**Class work**	**Evaluation 1**	**Evaluation 2**	**Report**	
2-0-2-2	5	10	10	15	5	10	5	60

Total Marks distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	60	40	2

End Semester Examination [ESE]: Pattern			
PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 2		2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5×8 = 40 marks) Time: 2.5 hours	40
	Total Marks: 0	Total Marks: [5×8 =40 marks]	

SYLLABUS
MODULE I: Introduction
Scope of Chemical Reaction Engineering, Classification of reactions, Rate equation and rate of reaction, Factors affecting rate of reaction, Chemical kinetics and Thermodynamics Equilibrium, Temperature dependency of rate constant from Arrhenius Collision and Transition state theories. Molecularity and order of reactions.
MODULE II: Non-Elementary Reactions
Difference between elementary and non- elementary reactions. Kinetic models and mechanisms for non-elementary reactions and types of reactors.
MODULE III: Homogeneous Reactions & Design of Ideal Reactors
Homogeneous Reactions: Interpretation of batch reactor data. Constant & Variable Volume batch reactor. Analysis: Differential method, Integral method, half-life method, method of excess and method of isolation (for Reversible and Irreversible reactions up to second order) Design of Ideal Reactors: Concept of ideality, Development of design equations for batch, tubular and stirred tank reactors for both constant and variable volume reactions. Evaluation of rate equations from data obtained in these reactors (Derivations in this module evaluated in the examination may be limited to first and order reactions)
MODULE IV: Multiple Reactor Systems & Design Of Reactors

Multiple Reactor Systems: Plug flow and Mixed flow reactors in Series & parallel reactions, Reactors of different types and sizes in series, Comparison of Ideal Reactors and General graphical comparison (only first order reactions to be considered) Design Of Reactors For Multiple Reactions: Design of Batch reactor, Plug and Mixed flow reactors for Parallel reactions (Only irreversible reactions must be considered)
MODULE V : Non-Isothermal Reactors:
Introduction, Material, Energy balances and conversions, Design procedure (For single/simple reactions only). Optimum temperature Progression.
Text books 1. Octave Levenspiel, Chemical Reaction Engineering, 3rd Edition, John Wiley & Sons, 2001 2. H Scott Fogler, "Elements of Chemical Reaction Engineering", Prentice Hall of India.
Reference books 1. James J Carberry, "Chemical & Catalytic Reaction Engineering", McGraw Hill 2. K.G Denbigh& J.C.R Turner, "Chemical Reactor Theory- An Introduction", Cambridge University Press.
3. Lanny D Schmidt, "The Engineering of Chemical Reactions", Oxford University Press. 4. Ronald W. Missen, Charles A. Mims, Bradley A. Saville, "Introduction to Chemical Reaction Engineering and Kinetics", John Wiley & Sons. 5. Smith J.M, "Chemical Engineering Kinetics," McGraw Hill.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1 (4 hours)	
1.1	Scope of Chemical Reaction Engineering, Classification of reactions	1
1.2	Rate equation and rate of reaction, Factors affecting rate of reaction,	1
1.3	Chemical kinetics and Thermodynamics Equilibrium,	1
1.4	Temperature dependency of rate constant from Arrhenius Collision and Transition state theories. Molecularity and order of reactions	1

MODULE II (3 hours)		
2.1	Difference between elementary and non- elementary reactions	1
2.2	Kinetic models and mechanisms for non-elementary reactions and types of reactors.	1
2.3	Kinetic models and mechanisms for non-elementary reactions and types of reactors.	1
MODULE III (8 hours)		
3.1	Interpretation of batch reactor data. Constant & Variable Volume batch reactor. Analysis: Differential method	1
3.2	Integral method, half-life method,	1
3.3	method of excess and method of isolation (for Reversible and Irreversible reactions up to second order	1
3.4	Concept of ideality, Development of design equations for batch reactor	1
3.5	Development of design equations for tubular and stirred tank reactors for both constant and variable volume reactions.	1
3.6	Development of design equations for tubular and stirred tank reactors for both constant and variable volume reactions.	1
3.7	Development of design equations for tubular and stirred tank reactors for both constant and variable volume reactions.	1
3.8	Evaluation of rate equations from data obtained in these reactors	1
MODULE IV (6 hours)		
4.1	Plug flow and Mixed flow reactors in Series & parallel reactions	1
4.2	Plug flow and Mixed flow reactors in Series & parallel reactions	1
4.3	Reactors of different types and sizes in series	1
4.4	Comparison of Ideal Reactors and General graphical comparison	1
4.5	Design of Batch reactor for Parallel reactions	1
4.6	Design of Plug and Mixed flow reactors for Parallel reactions	1
MODULE V (3 hours)		
5.1	Introduction, Material, Energy balances and conversions	1

5.2	Design procedure (For single/simple reactions only). Optimum temperature Progression.	1
5.3	Design procedure (For single/simple reactions only). Optimum temperature Progression.	1

LAB COMPONENT

Including laboratory experiments in a course is an excellent way to enhance the understanding of various concepts in the syllabus. It provides students with hands-on experience and practical application of the theoretical knowledge they acquire in the classroom. It also fosters critical thinking, problem-solving, and practical skills that are valuable in their academic and professional pursuits. Here are some key points to consider when incorporating laboratory experiments into a course:

Alignment with Course Objectives: Ensure that the laboratory experiments align with the course objectives and learning outcomes. The experiments should reinforce and complement the concepts taught in the classroom.

Relevance: Select experiments that are relevant to the course material and provide real-world examples of the concepts being discussed. This helps students see the practical applications of what they are learning.

Safety: Safety is paramount in a laboratory setting. Make sure that all experiments are conducted in a safe environment, and students are aware of the safety protocols and precautions.

Equipment and Materials: Ensure that the necessary equipment and materials are available and in good working condition. Students should have access to the tools and resources needed to conduct the experiments effectively.

Clear Instructions: Provide clear and detailed instructions for each experiment. This should include the purpose of the experiment, the procedures to be followed, data collection methods, and any specific requirements.

Data Analysis and Interpretation: Include a component for data analysis and interpretation in the laboratory reports. This encourages critical thinking and helps students draw meaningful conclusions from their experiments.

Variety: Offer a variety of experiments that cover different aspects of the course material. This can include quantitative experiments, qualitative observations, and even open-ended, exploratory experiments.

Feedback and Assessment: Develop a system for assessing and providing feedback on students' laboratory reports and performance. This assessment should contribute to their overall course grade.

Integration with Theory: Encourage students to connect the results of their experiments with the theoretical concepts discussed in the classroom. This reinforces their understanding and helps bridge the gap between theory and practice.
Practical Skills: Besides reinforcing theoretical knowledge, laboratory experiments should also help students develop practical skills, such as experimental design, data collection, and analysis.
Reflection: Encourage students to reflect on their experiences during the experiments. This can be done through post-lab discussions or written reflections, allowing students to think critically about what they learned.
Flexibility: Be open to adapting the laboratory component as needed. Sometimes, students may discover unexpected results or encounter challenges. This flexibility can turn such situations into valuable learning experiences.
Resources and Support: Provide access to resources, including lab manuals, research papers, and additional readings, to help students delve deeper into the concepts explored in the experiments.

LESSON PLAN FOR LAB COMPONENT

The concepts in the syllabus that can be illustrated through laboratory experiment should be included in the lab component part to ensure comprehensive coverage of the course.			
No.	Topic	No. of Hours [24]	Experiment
1	Kinetic study	2	Kinetic studies using batch reactor for an equimolar bimolecular reaction
2	Kinetic study	2	Kinetic studies using batch reactor for a non-equimolar bimolecular reaction
3	Reactor Design	2	Isothermal plug flow reactor
4	Reactor Design	2	Mixed flow reactor
6	RTD Study	2	RTD studies in a mixed flow reactor and plug flow reactor
8	RTD Study	2	RTD studies in packed bed reactor

9	Kinetic study	2	Effect of temperature on the kinetics of the reaction
10	Reactor Design	2	UV Photo Reactor
11	Kinetic study	2	Determination of activation energy
12	Reactor Design	2	Combined Flow Reactor

Incorporating a project component in a course complements theoretical learning and laboratory experiments by providing students with the opportunity to synthesize, apply, and deepen their understanding of course concepts. It also encourages critical thinking, problem-solving, and creativity, which are valuable skills for students' academic and professional growth. Here are some key points to consider when including a project component in a course to cover the concepts from the syllabus:

Alignment with Course Objectives: Ensure that the project aligns with the course objectives and learning outcomes. The project should provide an opportunity for students to apply the theoretical knowledge they've gained.
Relevance: Select project topics that are directly related to the course material. The project should enable students to explore and apply the concepts covered in the classroom and laboratory sessions.
Project Types: Consider various project types, such as group projects, case studies, or practical applications. The choice of project type should depend on the course's goals and the specific concepts being covered.
Clear Guidelines: Provide clear project guidelines and expectations. Include information on project deliverables, deadlines, and assessment criteria to ensure that students understand what is expected of them.
Student Choice: If possible, allow students to choose project topics that align with their interests or career goals. This can increase motivation and engagement.
Resources and Support: Ensure that students have access to the necessary resources, including literature, software, equipment, or guidance from instructors or mentors.
Interdisciplinary Approach: Encourage interdisciplinary projects that draw on concepts from multiple areas of the syllabus. This can promote a holistic understanding of the subject matter.
Peer Collaboration: Encourage collaboration among students for group projects. Teamwork can foster problem-solving skills and diverse perspectives.
Reflection and Presentation: Require students to reflect on their project experiences and present their findings to the class. This promotes critical thinking and communication skills.
Assessment Criteria: Clearly define how the project component will be graded.

Assess not only the final product but also the process, research, problem-solving, and communication skills.

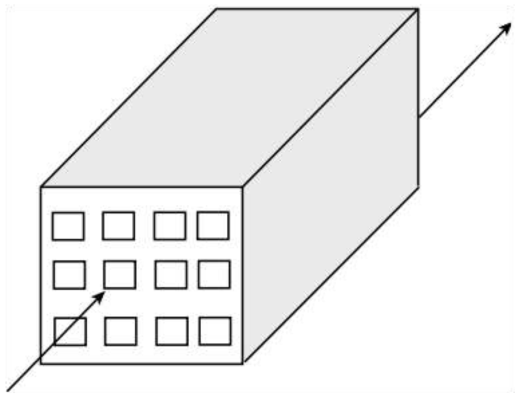
Feedback and Revision: Provide feedback on project proposals and guide students in the right direction. Allow them to revise and improve their work based on feedback.

Integration with Theory and Lab: Emphasize the connection between the project and the theoretical and laboratory components of the course. Encourage students to apply what they've learned in these sessions to their projects.

Real-World Applications: Whenever possible, choose projects that have real-world applications. This can help students see the practical relevance of their coursework. Sample project topics for students to work on:

1	A mixture of 28% and 72% air is charged to a flow reactor in which is oxidized. $$2SO_2 + O_2 \longrightarrow 2SO_3$$ (a) First, set up a stoichiometric table using only the symbols (i.e.,). (b) Next, prepare a second table evaluating the species concentrations as a function of conversion for the case when the total pressure is 1485 kPa (14.7 atm) and the temperature is constant at 2278 °C. (c) Evaluate the parameters and make a plot of each of the concentrations SO_2,SO3, N_2 as a function of conversion. d) Express the Rate Law for SO_2 Oxidation in Terms of Partial Pressures and Conversions.
2	The reversible gas-phase decomposition of nitrogen tetroxide, N_2O_4, to nitrogen dioxide, NO_2, $$N_2O_4 \rightleftarrows 2NO_2$$ is to be carried out at constant temperature. The feed consists of pure N_2O_4 at 340 K and 202.6 kPa (2 atm). The concentration equilibrium constant K_C, at 340 K is 0.1 mol/dm^3 and the rate constant is $0.5 min^{-1}$. (a) Set up a stoichiometric table and then calculate the equilibrium conversion in a constant-volume batch reactor. (b) Calculate the equilibrium conversion of in a flow reactor. (c) Assuming the reaction is elementary, express the rate of reaction solely as a function of conversion for a flow system and for a batch system. (d) Determine the CSTR volume necessary to achieve 80% of the equilibrium conversion.
3	Sixty-five percent of the ethylene produced is used in the manufacture of fabricated plastics, 20% for ethylene oxide, 16% for ethylene dichloride and ethylene glycol, 5% for fibers, and 5% for solvents. Determine the plug-flow reactor volume necessary to produce 300 million pounds of ethylene a year by cracking a feed stream of pure ethane. The reaction is irreversible and follows an elementary rate law. We want to achieve 80% conversion of ethane, operating the reactor isothermally at 1100 K and at a pressure of 6 atm. The specific reaction rate at 1,000 K is 0.072 s^{-1} and the activation energy is 82,000 cal/mol.

4	The gas-phase reaction $$2NOCl \longrightarrow 2NO + Cl_2$$

	is carried out at 425°C and 1641 kPa (16.2 atm). Pure NOCl is to be fed, and the reaction follows an elementary rate law.2 It is desired to produce 20 tons of NO per year in a microreactor system using a bank of ten microreactors in parallel. Each microreactor has 100 channels with each channel 0.2 mm square and 250 mm in length.  (a) Plot and analyze the molar flow rates as a function of volume down the length of the reactor. The volume of each channel is 10–5 dm^3. (b) Calculate the reactor volume necessary to achieve 85% conversion.
5	Select a homogeneous reaction system from an industrial context and analyze its behavior using both kinetics and thermodynamics. Investigate how reaction conditions impact the overall process.
6	Design a hypothetical chemical reactor based on the principles discussed in the course. Evaluate the reactor's efficiency under various conditions and propose improvements for optimization.
7	Investigate the design and operation of interconnected reactor systems. Analyze the advantages and challenges of series and parallel configurations in a given chemical process
8	Select a chemical reaction that is sensitive to temperature variations. Design and assess the performance of a non-isothermal reactor, considering safety, efficiency, and overall process control
9	Analyze the environmental impact of a chemical process, considering the stoichiometry, kinetics, and reactor design aspects. Propose sustainable practices and alternative reaction pathways
10	Propose an innovative design for a chemical reactor that addresses a specific industrial need. Considerations should include efficiency, safety, and environmental impact

<u>Note</u>:- Projects need not be restricted to the above topics. Students are encouraged to choose any application problems, in the course domain, which they desire to work on.

LESSON PLAN FOR PROJECT COMPONENT

The concepts in the syllabus that can be covered through the project shall be included in the project component part to ensure comprehensive coverage of the course through theory, lab and project sessions.

Total No. of Class Hours: 24

12 Hours of self-study hours also should be utilized for the development of the complete project.

No.	Topic	No. of Class Hours [24]
1	Preliminary Design of the Project	4
2	Zeroth presentation (4th week)	2
3	Project work - First Phase	4
4	Interim Presentation (7th and 8th weeks)	4
5	Project work - Final Phase & Report writing (discussions in class during project hours)	6
6	Final Evaluation and Presentation (11th and 12th weeks)	4

CO Assessment Sample Questions	
1	Analyze the reaction A+B→C in a homogeneous system. Determine the rate law. Compare and contrast the design principles of a continuous stirred-tank reactor (CSTR) and a plug-flow reactor (PFR). In what scenarios would one be more efficient than the other
2	Design an interconnected system of reactors for a multistep reaction. Discuss the advantages and challenges of using series and parallel configurations in your design.
3	Explain how temperature variations can impact the rate and selectivity of a chemical reaction. Propose design considerations for a non-isothermal reactor to optimize performance
	Explain how stoichiometry, kinetics, and reactor design are interconnected in a chemical process. Provide an example scenario where knowledge from each discipline is crucial.
5	Given a real-world chemical engineering problem involving a complex reaction, outline the steps you would take to analyze and solve the problem. Consider economic and environmental factors

24CHT503	TRANSPORT PHENOMENA	L	T	P	J	S	C	Year of Introduction
		2	1	0	0	2	3	2024

Preamble: This course introduces coupling between three transport phenomena, momentum, heat and mass transport with applications in various disciplines in engineering and science, and will demonstrate to the students the common mathematical structure of transport problems. The course will deal with flow problems involving Newtonian and non-Newtonian fluids, solid-state heat conduction and convection, binary diffusion with or without chemical reaction.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Explain the mechanisms of momentum, heat and mass transfer
CO2	Solve industrial problems involving isothermal steady state momentum transfer in simple geometries using shell momentum balance
CO3	Obtain analytical solutions of selected simple engineering steady state problems of heat transfer using shell energy balance
CO4	Obtain analytical solutions of selected simple engineering steady state problems of mass transfer using shell mass balance
CO5	Liken the similarities of transport process between momentum, heat and mass transport.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3											3
CO2	3											2
CO3	3	3										2
CO4	3	3										2
CO5	3	3										2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test 1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	**Attendance**	**Theory [L- T]**			**Total Marks**
		Assignment	**Test-1**	**Test-2**	
2-1-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I : Introduction

Momentum, Energy and Mass Transport operations, Newton's law of viscosity(NLV),
Newtonian and Non-Newtonian fluids, Fourier's law of heat conduction(FLHC), Fick's law of diffusion (FLD), Numerical problems.

MODULE II : Steady State Shell Momentum Balances

Different Flow situations, Steady state Shell momentum balances-Boundary conditions
applicable to momentum transport problems, Flow over a flat plate for Newtonian fluid and Non-Newtonian fluid, Flow through a circular tube for Newtonian fluid and Non-Newtonian fluid, Flow through Annulus. Flow between parallel plates and a slit. Numerical problems.

MODULE III : Steady State Shell Energy Balances

General Boundary conditions applicable to energy transport problems of chemical engineering, Heat conduction through compound walls, Overall heat transfer coefficient based on inner and outer surface area. Heat conduction with internal generation by electrical, nuclear, viscous energy sources, Numerical problems.

MODULE IV : Steady State Shell Mass Balances

Steady state shell mass balances, General Boundary conditions applicable to mass transport problems of chemical engineering, Diffusion through stagnant gas and liquid films, Equimolar counter diffusion. Numerical problems. Diffusion with homogeneous and heterogeneous reaction. Diffusion into falling film- Forced convection mass transfer. Numerical problems.

MODULE V : Analogies Between Momentum, Heat And Mass Transport & Equations Of Change

Reynold's, Prandtl's and Chilton & Colburn analogies. Equations of change: Various coordinate systems, Equation of continuity, Equation of motion; Navier-Stokes equation, Euler's equation, Equation of energy.

Text books

1. Bird R.B., Stewart W.C and Lightfoot F.N, Transport phenomena, John Wiley & Sons.

Reference books

1. Theodore L, Transport Phenomena for Engineers by, International text book Company, U.S.A
2. Geankoplis, Transport processes and unit operations, 3rd, PHI, 1997.
3. Welty, Wicks and Wilson, Fundamentals of Heat, Momentum and Mass Transfer, John Wiley.
4. John C Slattery, Momentum, Energy and Mass transfer in continua, McGraw Hill, Co.
5. Robert S. Brodkey and Harry C Hersing, Transport Phenomena a Unified Approach, McGraw Hill Book Co.
6. Bennet C U and Myers J E, Momentum, Heat and Mass Transfer, Tata McGraw Hill Publishing Co.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1 (7 hours)	
1.1	Momentum, Energy and Mass Transport operations	1
1.2	Newton's law of viscosity	1
1.3	Newtonian and Non-Newtonian fluids	1

1.4	Fourier's law of heat conduction	1
1.5	Fick's law of diffusion	1
1.6	Numerical problems	1
1.7	Numerical problems	1
MODULE II (7 hours)		
2.1	Different Flow situations, Steady state Shell momentum balances-Boundary conditions applicable to momentum transport problems	1
2.2	Flow over a flat plate for Newtonian fluid and Non-Newtonian fluid	1
2.3	Flow over a flat plate for Newtonian fluid and Non-Newtonian fluid	1
2.4	Flow through a circular tube for Newtonian fluid and Non-Newtonian fluid	1
2.5	Flow through Annulus	1
2.6	Flow between parallel plates and a slit	1
2.7	Numerical problems.	1
MODULE III (7 hours)		
3.1	General Boundary conditions applicable to energy transport problems of chemical engineering	1
3.2	Heat conduction through compound walls	1
3.3	Overall heat transfer coefficient based on inner and outer surface area	1
3.4	Heat conduction with internal generation by electrical, nuclear, viscous energy sources	1
3.5	Heat conduction with internal generation by electrical, nuclear, viscous energy sources	1
3.6	Heat conduction with internal generation by electrical, nuclear, viscous energy sources	1
3.7	Numerical problems.	1
MODULE IV (9 hours)		
4.1	Steady state shell mass balances	1
4.2	General Boundary conditions applicable to mass transport problems of chemical engineering	1

4.3	Diffusion through stagnant gas and liquid films	1
4.4	Diffusion through stagnant gas and liquid films	1
4.5	Equimolar counter diffusion. Numerical problems	1
4.6	Diffusion with homogeneous and heterogeneous reaction	1
4.7	Diffusion with homogeneous and heterogeneous reaction	1
4.8	Diffusion into falling film- Forced convection mass transfer. Numerical problems.	1
4.9	Diffusion into falling film- Forced convection mass transfer. Numerical problems.	1
MODULE V (6 hours)		
5.1	Reynold's, Prandtl's and Chilton & Colburn analogies	1
5.2	Reynold's, Prandtl's and Chilton & Colburn analogies	1
5.3	Equations of change: Various coordinate systems, Equation of continuity	1
5.4	Equation of motion; Navier-Stokes equation, Euler's equation	1
5.5	Equation of motion; Navier-Stokes equation, Euler's equation	1
5.6	Equation of energy	1

CO Assessment Sample Questions	
1	Explain the mechanism of momentum transfer between two parallel plates in which one is moving and the other stationary.
2	A fluid of constant density and viscosity is in a cylindrical container of radius R .The container is caused to rotate about its own axis (vertical) at an angular velocity Ω. Find the shape of the free surface at steady state.
3	Derive expression for temperature profile for the flow of incompressible Newtonian fluid between 2 co-axial cylinders, in which the outer cylinder rotates and inner one is held stationary.

4	A gaseous phase reaction $2A \rightarrow A_2$ is taking place on the surface of a catalyst. Assume that each catalyst particle is surrounded by a stagnant gas film through which A has to diffuse to reach catalyst. Using suitable assumptions develop an expression for the local rate of conversion and obtain the concentration profile in the gas film and molar flux through the film. Sketch the concentration profile.
5	Explain Reynold's analogy between heat, mass and momentum transfer.

24CHP504	Particle Technology	L	T	P	J	S	C	Year of Introduction
		2	1	2	0	4	4	2024

Preamble: This course gives the fundamental knowledge about the characteristics, properties, handling and processing of particles used for various industrial applications. Principles of size reduction and equipments used for size reduction are discussed. Design aspects of clarifiers, thickeners and filters are also covered.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Analyze particle size distribution of a given sample.
CO2	Select suitable equipment for handling materials in process industries like screening, classification, sedimentation, filtration etc. using fundamental concept.
CO3	Estimate the energy requirements for a specified reduction in size for a given material.
CO4	Select suitable method for storage and transportation of bulk solids in process industries.
CO5	Design unit operation equipment like clarifiers, thickeners, filters etc.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2						3	3	3		
CO2	3	2						3	3	3		2
CO3	3	3	3			2		3	3	3		2
CO4	3					2		3	3	3		2
CO5	3	3	3					3	3	3		

Assessment Pattern for Theory component

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	☐	☐	☐	☐
Understand	☐	☐	☐	☐
Apply	☐	☐	☐	☐
Analyse			☐	

Evaluate			□	
Create			□	

Assessment Pattern for Lab component

Bloom's Category	Continuous Assessment Tools	
	Class work	Test1
Remember		
Understand	□	□
Apply	□	□
Analyse	□	□
Evaluate	□	
Create	□	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Practical [P]		Total Marks
		Assignment	Test-1	Test-2	Class work	Lab Exam	
2-1-2-0	5	10	10	10	15	10	60

Total Marks distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	60	40	2.5

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 2		2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x 8 = 40 marks) Time: 2.5 hours	40

	Total Marks: 0	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Introduction and basic particle size analysis

Particle diameter and shape factor - particle size analysis - sieve analysis - particle size distribution - cumulative and differential methods of analysis - mean diameters – specific surface area and number of particles - screening - effectiveness and capacity of screens and factors affecting them - types of industrial screens-- sub- sieve analysis - pipette analysis -beaker decantation- elutriation.

MODULE II: Particle Settling and separation

Principles of free and hindered settling - equal settling particles - types of classifiers mechanical and non-mechanical, pneumatic classifiers - principles of mineral beneficiation methods - jigging - wilfley table - froth flotation, principles, additives, batch and continuous thickening - Kynch theory - design of continuous thickener.

MODULE III: Principle of size reduction

Laws of comminution - mechanism and efficiency of size reduction - principles of important size reduction equipments - types and selection of equipment for all ranges - closed circuit and open circuit grinding - free crushing and choke feeding - wet and dry grinding. Particle size enlargement.

MODULE IV: Principle of filtration

filtration - theory of constant pressure and constant rate filtration - cake porosity and compressibility - filter aids - optimum filtration cycle - types of batch and continuous filters (plate and frame, rotary, leaf filters-construction and working) -washing of filter cakes - centrifugal filtration (Top suspended basket centrifuge, reciprocating conveyor continuous centrifuge).

MODULE V: Air purification, particle storage & conveyors

Air separation methods - cyclone separation – electrostatic precipitation –Bag filters- venturi scrubber -Cottrell precipitator-. mixing of granular solids and pastes – mixing performance and effectiveness – mixers for non-cohesive and cohesive solids - storage and conveying of solids (numerical problems are not required) - silos, bins and hoppers - different types of conveyors (Belt, chain, screw, pneumatic) - selection of conveyors.

Text books 1. McCabe W.L., Smith J.C. and Harriot P., Unit Operations of Chemical Engineering, McGraw Hill, New York 2001. 6th Edition 2. Anup K Swain, Hemlata Patra, G.K.Roy ,Mechanical Operations, Mc-Graw- Hill Education.		
Reference books 1. Coulson J. M. and Richardson J.F; Chemical Engineering Vol. 1 & 2 Publishers: Butter worth – Heinemann Ltd. 2001-2002. 2. Christie J. GeanKoplis, Transport processes & Unit Operation, Prentice Hall international 3. Badger & Banchero, Introduction to Chemical Engineering, Mc-Graw- Hill Education 4. C.M. Narayan, B.C. Bhattacharyya, Mechanical Operations for Chemical Engineers, Khanna publishers.		
COURSE CONTENTS AND LECTURE SCHEDULE		
No.		No. of Hours
MODULE 1 (7 hours)		
1.1	Particle diameter and shape factor.	1
1.2	Particle size analysis - sieve analysis	1
1.3	Particle size distribution - cumulative and differential methods of analysis - mean diameters	1
1.4	Types of industrial screens	1
1.5	Specific surface area and number of particles	1
1.6	Screening - effectiveness and capacity of screens and factors affecting them	1
1.7	Sub-sieve analysis - pipette analysis - beaker decantation- elutriation	1
MODULE II (7 hours)		
2.1	Principles of free and hindered settling	1
2.2	Equal settling particles	1

2.3	Types of classifiers-mechanical and non-mechanical, pneumatic classifier	1
2.4	Principles of mineral beneficiation methods	1
2.5	Jigging - Wilfley table - froth flotation, principles, additives,	1
2.6	Batch and continuous thickening - kynch theory	1
2.7	design of continuous thickener	1
MODULE III (7 hours)		
3.1	Laws of comminution, mechanism and efficiency of size reduction	1
3.2	Principles of important size reduction equipment's	1
3.3	Principles of important size reduction equipment's	1
3.4	Types and selection of equipment for all ranges	1
3.5	Closed and open circuit grinding	1
3.6	Free crushing and choke feeding	1
3.7	Wet and dry grinding	1
MODULE IV (7 hours)		
4.1	Filtration - theory of constant pressure and constant rate filtration	1
4.2	Filtration - theory of constant pressure and constant rate filtration	1
4.3	Cake porosity and compressibility - filter aids - optimum filtration cycle	1
4.4	Types of batch and continuous filters (plate and frame, rotary, leaf filters-construction and working)	1
4.5	Types of batch and continuous filters (plate and frame, rotary, leaf filters-construction and working)	1

4.6	Washing of filter cakes - centrifugal filtration (Top suspended basket centrifuge, reciprocating conveyor continuous centrifuge)	1
4.7	Washing of filter cakes - centrifugal filtration (Top suspended basket centrifuge, reciprocating conveyor continuous centrifuge)	1
MODULE V (8 hours)		
5.1	Air separation methods-cyclone separation, bag filter	1
5.2	Venturi scrubber -Cottrell precipitator	1
5.3	Mixing of granular solids and pastes	1
5.4	Mixing performance and effectiveness	1
5.5	Mixers for non-cohesive and cohesive solids	1
5.6	Storage and conveying of solids (numerical problems are not required) - silos, bins and hoppers	1
5.7	Different types of conveyors (Belt, chain, screw, pneumatic)	1
5.8	Selection of conveyors.	1

LESSON PLAN FOR LAB COMPONENT

No.	Topic	No. of Hours	Experiment
1	Principles of free and hindered settling	2	Free Settling
2	Particle size analysis - sieve analysis	2	Sieve Analysis
3	Screening - effectiveness and capacity of screens and factors affecting them	2	Effectiveness of Screen
4	Laws of comminution, mechanism and efficiency of size reduction	2	Laws of Crushing
5	Sub-sieve analysis - pipette analysis - beaker decantation-elutriation	2	Beaker Decantation
6	Sub-sieve analysis - pipette analysis - beaker decantation-elutriation	2	Pipette Analysis
7	Principles of free and hindered settling	2	Sedimentation
8	Types of batch and continuous filters (plate and frame, rotary, leaf filters-construction and working)	2	Leaf Filter
9	& (b) Types of batch and continuous filters (c) Air separation methods-cyclone separation (d) Sub-sieve analysis - elutriation	2	Study of a. Plate and Frame Filter press b. Rotary drum filter c. Cyclone Separator d. Elutriator

10	Types of batch and continuous filters (plate and frame, rotary, leaf filters- construction and working) Principles of mineral beneficiation methods	2	Study of a. Ball Mill b. Hammer Mill c. Jaw Crusher d. Basket Centrifuge e. Wilfey Table f. Belt Conveyor g. Mineral Jig h. Froth Floatation Cell

CO Assessment Sample Questions	
1	A quartz mixture is screened through a 10- mesh screen. The cumulative screen analysis of feed, overflow and underflow are given in the table. Calculate the mass ratios of the overflow and underflow to feed and the overall effectiveness of the screen.
2	Develop a detailed process for the beneficiation of metal in iron plant.
3	List the advantages of Bond's law over Rittinger's law. A mill crushes 50 tons per hour of solids from 4 cm to 1 cm and consumes 50 KW power. Determine the power required to reduce the size of the product from 1 cm to 5 mm for the same capacity.
4	List and explain different storage methods used in food processing industries.
5	Illustrate the working of mixer extruders. List its industrial applications.

Table for question 1:

Mesh	D_p (mm)	feed	overflow	underflow
4	4.6	0	0	0
6	3.3	0.02	0.07	0
8	2.3	0.15	0.43	0
10	1.6	0.47	0.85	0.19
14	1.1	0.73	0.97	0.58
20	0.8	0.88	0.99	0.83
28	0.5	0.94	1	0.91
35	0.4	0.96		0.94
65	0.2	0.98		0.97
pan		1		1

24HUT565	ECONOMICS AND MANAGEMENT FOR CHEMICAL INDUSTRIES	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: The economics and management of chemical industries is one of the key areas where Chemical Engineer needs focus. This course focuses on economic and cost analysis of engineering projects, giving insights on tools used for cost estimation, profitability analysis and taking decision among alternatives. The students will be able to get a sound understanding of concepts and principles of engineering economy and to develop proficiency with methods for making rational decisions regarding problems likely to be encountered in professional practice.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Apply the concept of time value of money, unacost, capitalized cost etc. for comparing projects of equal and unequal duration.
CO2	Explain the concept of depreciation and apply different methods for calculating depreciation in real life projects.
CO3	Apply different techniques and tools for cost estimation of the projects
CO4	Utilize different methods for calculating profitability for project selection and ranking.
CO5	Apply the concept of break even analysis for selecting / designing a project.
CO6	Explain the principle of accounting, prepare financial statements and analyze the financial status of the company.

CO - PO MAPPING

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	3	3	3									
CO2	3	3									3	
CO3	3	3	3								3	
CO4	3	3	3									
CO5	3	3	3									
CO6	3	3									3	

Assessment Pattern

Bloom's Category	**Continuous Assessment Tools**			**End Semester Examination**
	Test1	Test2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	**Attendance**	**Theory [L- T]**			**Total Marks**
		Assignment	**Test-1**	**Test-2**	
3-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 HOURS

End Semester Examination [ESE]: Pattern

PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I : Equivalence and cost comparisons

Equivalence and cost comparisons:- Time value of money and equivalence, equations used in economic analysis, compound interest and continuous interest, unacost, capitalized cost, cost comparison with equal and unequal duration of service life, depreciation and taxes, nature of depreciation, methods of determining depreciation, straight line, declining balances, sum of years digits and sinking fund.

MODULE II : Cost estimation

Cost Estimation: Cost indices, material cost indices, labour cost indices, William's six tenth factor, location index, types of cost estimates:- order of magnitude estimate, study estimate, preliminary estimate, definitive estimate, detailed estimate, techniques of cost estimates: - conference techniques, comparison techniques graphic relationship, tabular relationship, unit rate techniques, lang factor method,
hand factor method, Chilton method, miller method, Peter's and Timmerhaus ratio factor method, Items for capital cost estimates, product cost estimates, direct production cost, administration expenses, items for total product cost estimates, elements of complete costs, start up costs.
MODULE III : Profitability analysis
Profitability analysis, mathematical methods for profitability evaluation, payout time, payout time with interest, return on average investment, Return on original investment, net present value, net present value index, DCF rate of return, incremental analysis.
MODULE IV : Breakeven and minimum cost analysis
Breakeven and minimum cost analysis, variable cost and fixed cost, Break even analysis, economic production chart for 100% capacity, above 100% capacity and dumping, non-linear economic production chart, Inflation, unaburden.
MODULE V : Principles of accounting
Principles of accounting, accounting definition, trial balance, profit and loss accounts, balance sheet , financial ratios related to balance sheet and profit and loss account, canons of ethics of engineers.
Text books 1. Jelen F.C., Cost and Optimisation Engineering, McGraw Hill 2. Peters & Timmerhaus, Plant Design & Economics for Chemical Engineering, McGraw Hill
Reference books 1. Davies G.S., Process Engineering Economics, Chem. Eng. Ed. Dev. Centre, IIT Madras 2. Schweyer, Process Engineering Economics, McGraw Hill 3. Tyler, Chemical Engineering Cost Estimation 4. Aries & Newton, Chemical Engineering & Cost Estimation 5. Happel, Chemical Process Economics, Marcel Decker

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE 1 (8 hours)		

1.1	Time value of money and equivalence	1
1.2	Equations used in economic analysis, compound interest and continuous interest	1
1.3	Unacost, capitalized cost	1
1.4	Cost comparison with equal and unequal duration of service life	1
1.5	Cost comparison with equal and unequal duration of service life	1
1.6	Depreciation and taxes, nature of depreciation	1
1.7	Methods of determining depreciation, straight line, declining balances	1
1.8	Sum of years digits and sinking fund methods	1
	MODULE II (8 hours)	
2.1	Cost indices, material cost indices, labour cost indices, William's six tenth factor, location index	1
2.2	Cost indices, material cost indices, labour cost indices, William's six tenth factor, location index	1
2.3	Types of cost estimates:- order of magnitude estimate, study estimate, preliminary estimate, definitive estimate, detailed estimate	1
2.4	Techniques of cost estimates:- conference techniques, comparison techniques graphic relationship, tabular relationship, unit rate techniques, lang factor method, hand factor method, Chilton method, miller method, Peter's and Timmerhaus ratio factor method	1
2.5	Techniques of cost estimates:- conference techniques, comparison techniques graphic relationship, tabular relationship, unit rate techniques, lang factor method, hand factor method, Chilton method, miller method,	1

	Peter's and Timmerhaus ratio factor method	
2.6	Techniques of cost estimates:- conference techniques, comparison techniques graphic relationship, tabular relationship, unit rate techniques, lang factor method, hand factor method, Chilton method, miller method, Peter's and Timmerhaus ratio factor method	1
2.7	Items for capital cost estimates, product cost estimates, direct production cost, administration expenses	1
2.8	Items for total product cost estimates - elements of complete costs - start up costs	1
MODULE III (6 hours)		
3.1	Mathematical methods for profitability evaluation, payout time, payout time with interest	1
3.2	Mathematical methods for profitability evaluation, payout time, payout time with interest	1
3.3	Return on average investment, Return on original investment	1
3.4	Net present value, net present value index	1
3.5	DCF rate of return	1
3.6	Incremental analysis	1
MODULE IV (6 hours)		
4.1	Variable cost and fixed cost	1
4.2	Break even analysis	1
4.3	Economic production chart for 100% capacity, above 100% capacity and dumping	1

4.4	Economic production chart for 100% capacity, above 100% capacity and dumping	1
4.5	Non-linear economic production chart	1
4.6	Inflation, unaburden	1
MODULE V (8 hours)		
5.1	Accounting definition, trial balance	1
5.2	Accounting definition, trial balance	1
5.3	Profit and loss accounts	1
5.4	Profit and loss accounts	1
5.5	Balance sheet	1
5.6	Balance sheet	1
5.7	Financial ratios related to balance sheet and profit and loss account	1
5.8	Canons of ethics of engineers	1

CO Assessment Sample Questions	
1	A heat exchanger costs Rs.1, 25,000 and salvage value is 5,000/- after 9 years. Operating cost is 10,000/-. A similar heat exchanger cost 2, 30,000/- with an annual operating cost of 25,000/- and salvage value of 20,000/- lasts 15 years. Which one is economical?
2	Explain any two methods for calculating depreciation.
3	Explain order of magnitude and study estimates for cost estimation.
4	Discuss the mathematical criteria used for profitability analysis.
5	If price/unit in Rs. is (1000-D/5), where D is the annual demand, the total cost per year can be approximated as (1000+2D2). Determine the value of D that maximizes the profit.

6	Explain the process of finding gross profit and net profit from profit and loss account.

24MCT506	CONSTITUTION OF INDIA	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	0	2024

Preamble: To familiarize the students with key elements of the Indian Constitution. The course covers the goals and policies framed under the constitution for the national well- being. It will enable students to demonstrate how vibrant is our constitution and the various institutions functioning under it.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Explain the basic postulates of Indian Constitution and its growth trajectory.
CO 2	Evaluate the human rights conditions and the moral standards of the Indian constitution.
CO 3	Analyze the interdependence of governance mechanisms through legislation, executive and judicial administration.
CO 4	Evaluate the functioning of state governments in India in view of decentralization of authority and participatory governance.
CO 5	Assess the effectiveness of division of power between Centre and States in India.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1						□		□		□		□
CO 2						□		□		□		□
CO 3						□		□		□		□
CO 4						□		□		□		□
CO 5						□		□		□		□

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test2	Other tools	
Remember	□	□	□	□
Understand	□	□	□	□
Apply				
Analyze				
Evaluate				
Create				

Mark Distribution of CIA					
Course Structure [L-T-P-J]	Attendance	Theory [L]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Marks distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 Hrs

End Semester Examination [ESE]: Pattern			
PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub-divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS
MODULE I: Introduction of the Indian Constitution
Definition of constitution, historical background, salient features of the Indian constitution. Preamble of the constitution, union and its territory. Meaning of citizenship, types, termination of citizenship.
MODULE II: Fundamental Rights and Duties
Definition of state, fundamental rights, general nature, classification, right to equality, right to freedom, right against exploitation. Right to freedom of religion, cultural and educational rights, right to constitutional remedies, Protection in respect of conviction for offences. Directive principles of state policy, classification of directives, fundamental duties.
MODULE III: Union executive and Parliament
The Union executive, The President, the Vice President, the Council of Ministers, the Prime Minister, Attorney-General, functions. The Parliament, composition, Rajya Sabha, Lok Sabha, qualification and disqualification of membership, functions of Parliament. Union judiciary, the Supreme court, jurisdiction, appeal by special leave.
MODULE IV: State Executive and State legislature

The State executive, the Governor, the Council of Ministers, the Chief Minister, Advocate general, Union territories. The state legislature, composition, qualification and disqualification of membership, functions. The State Judiciary, the High court, jurisdiction, writ jurisdiction. Local government-Panchayat raj system- with special reference to 73rd and 74th amendment.

MODULE V: Governance and Constitution

Relations between the Union and the States, legislative relation, administrative relation, financial relations, Inter State council, finance commission. Emergency provision, freedom of trade and commerce. Comptroller and Auditor General of India, public services, public service commission, Administrative Tribunals. Amendment of the constitution-meaning, procedure and limitations. Election provisions and electoral process.

Textbooks

1. D.D.Basu, Introduction to the constitution of India, LexisNexis, New Delhi,25e,2021
2. P M Bhakshi, The Constitution of India, Universal Law, 14e ,2017
3. M.V. Pylee, "Introduction to the Constitution of India", 4th Edition, Vikas publication, 2005.
4. K. Sharma, Introduction to the Constitution of India, Prentice Hall of India, New Delhi, 2002.

Reference books

1. Granville Austin, 2000. The Indian Constitution: Cornerstone of a Nation. Melbourne: Oxford University Press.
2. Merunandan, "Multiple Choice Questions on Constitution of India" , 2nd Edition, Meraga publication, 2017
3. D.C. Gupta, Indian Government and Politics, Vikas publishing House, New Delhi.

COURSE CONTENTS AND LECTURE SCHEDULE		
No.		No. of Hours 34
	MODULE 1 (4 Hours)	
1.1	Definition of Constitution- Historical back-ground	1
1.2	Salient features of the Constitution	1
1.3	Preamble of the Constitution-Union and its territory.	1
1.4	Meaning of Citizenship-types- termination of citizenship	1
	MODULE II (8 Hours)	
2.1	Definition of state, fundamental rights,	1
2.2	General nature, classification, right to equality.	1
2.3	Right to freedom, right against exploitation.	1
2.4	Right to freedom of religion.	1
2.5	Cultural and educational rights, right to constitutional	1

	remedies	
2.6	Protection in respect of conviction for offences.	1
2.7	Directive principles of state policy,	1
2.8	Classification of directives, fundamental duties.	1
	MODULE III (8 Hours)	
3.1	The Union executive, The President.	1
3.2	The Union executive, The Vice President.	1
3.3	The council of ministers, the Prime minister, Attorney - General, functions.	1
3.4	The Parliament, composition, Rajya Sabha, Lok Sabha.	1
3.5	Qualification and disqualification of membership,	1
3.6	Functions of parliament.	1
3.7	Union judiciary, the Supreme court.	1
3.8	Jurisdiction, appeal by special leave.	1
	MODULE IV (7 Hours)	
4.1	The state executive, the Governor, the council of ministers.	1
4.2	The Chief Minister, advocate general, union territories.	1
4.3	The state Legislature, composition,	1
4.4	Qualification and disqualification of membership, functions.	1
4.5	The state judiciary, the high court,	1
4.6	Jurisdiction, writ jurisdiction.	1
4.7	Local government, Panchayat raj system-with special reference to 73^{rd} and 74^{th} amendment.	1
	MODULE V (7 Hours)	
5.1	Relation between the union and the states, legislative relation, administrative relation.	1
5.2	Financial relations, Inter -State council, finance commission.	1
5.3	Emergency provision, freedom of trade and commerce.	1
5.4	Comptroller and Auditor General of India, public services,	1
5.5	Public service commission, administrative tribunals.	1
5.6	Amendment of the constitution-meaning, procedure and limitations.	1
5.7	Election provisions and electoral process.	1

CO Assessment Questions	
CO1	a. Examine the salient features of the Indian constitution. b. “Secularism is the foundation of democracy”. Explain
CO2	“The constitution has ensured certain rights to the minorities under Article 30”- Examine.

CO3	Discuss the various ways Parliament ensures accountability of the executive.
CO4	Evaluate the impact of the 73^{rd} and 74^{th} constitutional amendments on the decentralization of power and the functioning of panchayats and municipalities in India.
CO5	Describe the division of powers between Central and state government in India.

24EST508	ENERGY &ENVIRONMENTAL AUDIT	L	T	P	J	S	C	Year of Introduction
		2	0	0	0	2	2	2024

Preamble: The objective of the course is to understand energy scenario and general
aspects of energy audit and environmental audit. This course is expected to equip students with the knowledge and skills needed to conduct thorough assessments of energy consumption and environmental impact within organizations. As the global community grapples with pressing environmental challenges and seeks sustainable solutions, the importance of energy and environmental auditing has never been more significant.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to:

CO1	Describe the trends on energy use, policies and energy conservation strategies adopted in India
CO2	Describe the salient features of energy conservation act and related policies
CO3	Describe general aspects of energy audit and prepare energy audit reports.
CO4	Describe various concepts of Environmental Impact Assessment(EIA)
CO5	Prepare EIA report for getting Environmental clearance

CO - PO MAPPING

CO	**PO1**	**PO 2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	2					2						2
CO2	2					2						2
CO3	2					2						2
CO4	2					2	2					2
CO5	2					2	2			2		2

Assessment Pattern

Bloom's Category	**Continuous Assessment Tools**			**End Semester Examination**
	Test1	**Test 2**	**Other tools**	
Remember	✔	✔	✔	
Understand	✔	✔	✔	
Apply	✔	✔	✔	
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

23ES4507

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
2-0-0-0	5	35	30	30	100

SYLLABUS

MODULE I: Energy Scenario

Introduction, primary and secondary energy, commercial and non-commercial energy, Renewable and non-renewable energy India energy scenario, sector wise energy consumption in India, energy needs of a growing economy, Integrated energy policy, Long term. Energy scenario of India, energy conservation and its importance.

MODULE II: Energy Conservation act and related policies

Industrial Heating furnaces, Salient feature of energy Conservation Act 2001 and The Energy Conservation (Amendment) Act 2010, schemes of BEE under the energy Conservation Act-2001

MODULE III: Energy management and audit

Energy Audit definition, Need for energy audit, Types of energy audit and approach, Understanding energy costs, Benchmarking, Energy performance, Matching energy usage to requirements, Maximizing system efficiencies, Optimising input energy requirements, Fuels and Energy substitution, Instruments and metering for energy audit, Bureau of Energy Efficiency regulations.

MODULE IV: Concepts of Environmental Impact Assessment

Concepts of Environmental Impact Assessment: Environment; Environmental Impacts; Environmental Impact Analysis; Environmental Impact Assessment And Environmental Impact Statement; EIA- As An Integral Part of The Planning Process

MODULE V: Environmental Audit

Environmental Audit: Definition; Objectives; Scope, Coverage - EIA notification September 2006 and amendments: Categorization of projects, Procedure for getting environmental clearance. Public participation in environmental decision-making process. Case studies on EIA for Industries and Infrastructure projects

Text book 1. Environmental auditing: Fundamentals and techniques1987 by J. Ladd Greeno 2. Robert Ristirer and Jack P. Kraushaar, "Energy and the environment", Willey, 2005. 3. General Aspects of Energy Management and Energy Audit, Bureau of Energy Efficiency 4. Environmental Impact Analysis Handbook – by Rau Whooten; McGraw Hill publications
Reference books 1. Murphy, W. R., Energy Management, Elsevier, 2007. 2. Smith, C. B., Parmenter K., Energy Management Principles, Pergamon, 1981 3. Turner, W. C., Doty, S. and Truner, W. C., Energy Management Hand book, 7th edition, Fairmont Press, 2009. 4. Energy and the Challenge of Sustainability, World energy assessment, UNDP New York, 2004. 5. AKN Reddy, RH Williams, TB Johansson, Energy after Rio, Prospects and challenges, UNDP, United Nations Publications, New York, 1997

COURSE CONTENTS AND LECTURE SCHEDULE		
No.		No. of Hours
	MODULE 1 (4 hours)	
1.1	Introduction, primary and secondary energy, commercial and non-commercial energy	1
1.2	Renewable and non-renewable energy India energy scenario, sector wise energy consumption in India	1
1.3	energy needs of a growing economy, Integrated energy policy, Long term.	1
1.4	Energy scenario of India, energy conservation and its importance.	1
	MODULE II (4 hours)	
2.1	Industrial Heating furnaces, Salient feature of energy Conservation Act 2001	1
2.2	Industrial Heating furnaces, Salient feature of energy Conservation Act 2001	1
2.3	The Energy Conservation (Amendment) Act 2010,	1

2.4	schemes of BEE under the energy Conservation Act-2001	1
MODULE III (6 hours)		
3.1	Energy Audit definition, Need for energy audit, Types of energy audit and approach	1
3.2	Energy Audit definition, Need for energy audit, Types of energy audit and approach	1
3.3	Understanding energy costs, Benchmarking, Energy performance	1
3.4	Matching energy usage to requirements, Maximizing system efficiencies	1
3.5	Optimising input energy requirements, Fuels and Energy substitution	1
3.6	Instruments and metering for energy audit, Bureau of Energy, Efficiency regulations.	1
MODULE IV (4 hours)		
4.1	Concepts of Environmental Impact Assessment : Environment; Environmental Impacts;	1
4.2	Environmental Impact Analysis	1
4.3	Environmental Impact Assessment And Environmental Impact statement	1
4.4	EIA- as An Integral Part of The Planning Process	1
MODULE V (6 hours)		
5.1	Environmental Audit: Definition; Objectives; Scope, Coverage	1
5.2	EIA notification September 2006 and amendments	1
5.3	Categorization of projects, Procedure for getting environmental clearance.	1
5.4	Public participation in environmental decision making process.	1
5.5	Case studies on EIA for Industries and Infrastructure projects	1

5.6	Case studies on EIA for Industries and Infrastructure projects	1

CO Assessment Sample Questions	
1	Explain the difference between energy conservation and energy efficiency with an example.
2	Explain five important features of energy conservation act 2001.
3	Explain the major difference between primary energy audit and detailed energy audit.
4	Write a note on Environmental Impact analysis.
5	Describe the procedure to get environmental clearance for a project.

FIFTH SEMESTER HONOUR

24CHH509	ADVANCED HEAT TRANSFER	L	T	P	J	S	C	Year of Introduction
		4	0	0	0	4	4	2024

Preamble: The course covers topics such as one-dimensional steady state conduction, multidimensional conduction, unsteady state conduction, heat transfer through extended surfaces, convective and radiative heat transport analysis, heat exchanger network design.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Apply the concepts of conduction heat transfer to the design of heat-transfer equipment and solve related engineering problems.
CO2	Explain the concept and applications of heat transfer through extended surfaces
CO3	Explain the phenomenon of unsteady state conduction of various types.
CO4	Apply the concepts of convection and radiation heat transfer to solve complex heat transfer problems.
CO5	Design a heat exchanger network

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	2									2
CO2	3											2
CO3	3											2
CO4	3	2	2									2
CO5	3	2	3	2								2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test 1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	**Attendance**	**Theory [L- T]**			**Total Marks**
		Assignment	**Test-1**	**Test-2**	
4-0-0-0	5	15	10	10	40

Total Mark distribution

Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 HOURS

End Semester Examination [ESE]: Pattern

PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I : Conduction heat transfer (11 hours)

Review of conduction convection and thermal radiation fundamentals. Thermal conductivity. Temperature and pressure dependence of thermal conductivity. Thermal conductivity of solids, liquids and gases. Combined mechanisms of heat transfer. The general differential equation for energy transfer. Steady state one-dimensional conduction with and without heat generation.

MODULE II : Heat transfer from extended surfaces (12 hours)

Heat transfer from extended surfaces. Rectangular plate fin of uniform cross section: Long fins, Fin with insulated end, Fins with convection off the end. Pin fin (spine) of uniform cross section. Efficiency and effectiveness of fins. Error estimation in temperature measurement. Multi-dimensional heat conduction - Conduction in two dimensional systems: Analytical solution to a thin, infinitely long rectangular plate without any heat source.

MODULE III : Unsteady state conduction (9 hours)

Unsteady state conduction. Lumped parameter analysis; Systems with negligible internal resistance. Response time of a temperature measuring instrument. Systems with negligible surface resistance. Heat flow in an infinitely thick plate (Semi-infinite body). Systems with finite surface and internal resistance. Chart
solutions of transient heat conduction problems.

MODULE IV : Convection and radiation heat transfer (9 hours)

Convection heat transfer. The convective heat transfer coefficient. The basic equations: continuity equation, the momentum equation and the energy equation. Exact analysis of the laminar boundary layer. Approximate analysis of the thermal boundary layer. Radiation heat transfer: Nature of radiation. Thermal radiation. The intensity of radiation. Radiant heat transfer between black bodies. Radiant heat transfer between gray surfaces. Radiation from gases. The radiation heat transfer
coefficient.

MODULE V : Heat exchanger network design (7 hours)

Heat Exchanger Network Design - the difference between streams and branches, the pinch design method, Grid diagram, Stream splitting design for single pinch networks.

Text books

1. Welty J.R et al., Fundamentals of Momentum, Heat and Mass Transfer, John Wiley & Sons
2. Hollman J.P., Heat Transfer, McGraw Hill
3. Dutta B.K., Heat Transfer: Principles and Applications, Prentice Hall India
4. Robin Smith, Chemical Process Design and Integration, John Wiley and Sons. Ltd., New Delhi, 2005.

Reference books

1. Bird et al., Transport Phenomena, John Wiley & Sons.
2. Foust A.S et al., Principles of Unit Operations, John Wiley & Sons.
3. McCabe W.L., Smith J.C. &Harriott P., Unit Operations in Chemical Engineering, McGraw Hill
4. Coulson J.M. & Richardson J.F., Chemical Engineering, Vol. I and II, ELBS, Pergamon Press
5. Geankopolis C J, Transport Processes and Separation Process Principles, Prentice Hall of India, 4th Edition, Eastern Economy Edition (2004)
6. Incropera F P and DeWitt D P, Introduction to Heat Transfer, 2nd Ed John Wiley New York (1996).
7. M.Necati. Özizik, Heat transfer - A Basic Approach, McGraw-Hill College (1985)
8. Kern D.Q., Process Heat Transfer, McGraw Hill

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1	
1.1	Review of conduction convection and thermal radiation fundamentals.	1
1.2	Thermal conductivity. Temperature and pressure dependence of thermal conductivity. Thermal conductivity of solids, liquids and gases.	1

1.3	Thermal conductivity. Temperature and pressure dependence of thermal conductivity. Thermal conductivity of solids, liquids and gases.	1
1.4	Combined mechanisms of heat transfer.	1
1.5	The general differential equation for energy transfer.	1
1.6	The general differential equation for energy transfer.	1
1.7	Steady state one-dimensional conduction with and without heat generation	1
1.8	Steady state one-dimensional conduction with and without heat generation	1
1.9	Steady state one-dimensional conduction with and without heat generation	1
1.10	Steady state one-dimensional conduction with and without heat generation	1
1.11	Steady state one-dimensional conduction with and without heat generation	1
MODULE II		
2.1	Heat transfer from extended surfaces. Rectangular plate fin of uniform cross section: Long fins, Fin with insulated end, Fins with convection off the end.	1
2.2	Heat transfer from extended surfaces. Rectangular plate fin of uniform cross section: Long fins, Fin with insulated end, Fins with convection off the end.	1
2.3	Pin fin (spine) of uniform cross section.	1
2.4	Efficiency and effectiveness of fins.	1
2.5	Efficiency and effectiveness of fins.	1
2.6	Error estimation in temperature measurement.	1
2.7	Multi-dimensional heat conduction: Two- and three-dimensional systems (introduction only). Numerical solutions.	1
2.8	Multi-dimensional heat conduction: Two- and three-dimensional systems (introduction only). Numerical solutions.	1

2.9	Multi-dimensional heat conduction: Two- and three-dimensional systems (introduction only). Numerical solutions.	1
2.10	Multi-dimensional heat conduction: Two- and	1
	three-dimensional systems (introduction only). Numerical solutions.	
2.11	Multi-dimensional heat conduction: Two- and three-dimensional systems (introduction only). Numerical solutions.	1
2.12	Multi-dimensional heat conduction: Two- and three-dimensional systems (introduction only). Numerical solutions.	1
MODULE III		
3.1	Unsteady state conduction. Lumped parameter analysis; Systems with negligible internal resistance	1
3.2	Unsteady state conduction. Lumped parameter analysis; Systems with negligible internal resistance	1
3.3	Unsteady state conduction. Lumped parameter analysis; Systems with negligible internal resistance	1
3.4	Response time of a temperature measuring instrument.	1
3.5	Response time of a temperature measuring instrument.	1
3.6	Systems with negligible surface resistance.	1
3.7	Heat flow in an infinitely thick plate (Semi-infinite body). Systems with finite surface and internal resistance.	1
3.8	Heat flow in an infinitely thick plate (Semi-infinite body). Systems with finite surface and internal resistance.	1
3.9	Chart solutions of transient heat conduction problems.	1
MODULE IV		
4.1	Convection heat transfer. The convective heat transfer coefficient.	1
4.2	The basic equations: Continuity equation, the momentum equation and the energy equation.	1
4.3	Exact analysis of the laminar boundary layer. Approximate analysis of the thermal boundary layer.	1
4.4	Exact analysis of the laminar boundary layer. Approximate analysis of the thermal boundary layer.	1

4.5	Radiation heat transfer: Nature of radiation. Thermal radiation. The intensity of radiation.	1
4.6	Radiation heat transfer: Nature of radiation. Thermal radiation. The intensity of radiation.	1
4.7	Radiant heat transfer between black bodies. Radiant heat transfer between gray surfaces.	1
4.8	Radiant heat transfer between black bodies. Radiant heat transfer between gray surfaces	1
4.9	Radiation from gases. The radiation heat transfer coefficient.	1
MODULE V		
5.1	Heat Exchanger Network Design - the difference between streams and branches	1
5.2	Heat Exchanger Network Design - the difference between streams and branches	1
5.3	The pinch design method	1
5.4	The pinch design method	1
5.5	Grid diagram	1
5.6	Grid diagram	1
5.7	Stream splitting design for single pinch networks.	1

CO Assessment sample questions	
1	A thick-walled tube of stainless steel having a k = 21.63 W/mK with dimensions of 0.0254 ID and 0.0508 OD is covered with a 0.0254 m thick layer of insulation (k = 0.2423 W/mK). The inside wall temperature of the pipe is 811 K and the outside surface of insulation is at 310.8 K. For a 0.305 m length of pipe, calculate the heat loss and also the temperature at the interface between the metal and the insulation.
2	Derive the expression for temperature distribution and heat flux for a rectangular fin.
3	Derive the expression for temperature distribution of a solid undergoing transient conduction. Assume negligible internal resistance.

4	Air at 293 K is flowing along a heated plate at 407 K with a velocity of 3 m/s. The plate is 2 m long. The heat transferred from the first 40 cm from the leading edge of the plate is 1450 W. Determine the width of the plate. Data: Properties of air at the mean film temperature of 350 K are: ρ= 0.998 kg/m^3, ν= 20.76*10^{-6} m^2/s, k = 0.03 W/m.K, Pr = 0.697
5	A problem table analysis for part of a high temperature process reveals that for ΔTmin = 20℃ the process requires 9.2 MW of hot utility, 6.4 MW of cold utility and the pinch is located at 520 ℃ for hot streams and 500 ℃ for cold streams. The process stream data for the heat recovery network problem are given below. Design a MER HEN.

Stream		Supply temperature (◦C)	Target temperature (◦C)	Heat capacity flowrate (MW·K−1)
No	Type			
1	Hot	720	320	0.045
2	Hot	520	220	0.04
3	Cold	300	900	0.043
4	Cold	200	550	0.02

24CHH510	TECHNOLOGIES FOR CLEAN AND RENEWABLE ENERGY PRODUCTION	L	T	P	J	S	C	Year of Introduction
		4	0	0	0	4	4	2024

Preamble: The course deals with the production of energy from different fossil fuels
through cleaner routes as well as from renewable resources. It is intended to help the students keep their knowledge upgraded with the current thoughts and newer technology options along with their advances in the field of the utilization of different types of energy resources for cleaner energy production.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Describe the advanced clean routes for energy production from coal.
CO 2	Evaluate various methods of clean energy production from crude petroleum.
CO 3	Explain the energy production via solar techniques.
CO 4	Describe the energy production methods via wind and ocean systems.
CO 5	Explain the methods of energy production from biomass and geothermal resources.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	3	3										
CO 2	3	3										
CO 3	3	3										
CO 4	3	3										
CO 5	3	3										

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
4-0-0-0	5	5	10	10	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Clean route for energy production from coal (10 hrs)

Clean route for energy production from coal: Pre-treatment of coal- Desulphurization and demineralization. Modification processes: Fluidized bed reactor, super critical boiler and flue gas clean up. Advanced techniques of energy production from coal: Oxy-fuel combustion, chemical looping combustion, gasification, direct liquefaction and underground coal gasification.

MODULE II: Cleaner Routes for Energy Production from Petroleum Crude (10 hrs)

Overview of Petroleum Crude: Composition, Types, and Properties, Environmental Impacts of Conventional Energy Production, Clean Energy production from Petroleum crude: Thermal Depolymerization(TDP),LNG, CNG, Hydrocracking and Hydrotreating Processes, Gasification for Syngas and Hydrogen Production

MODULE III: Energy production from solar technologies (9 hrs)

Solar thermal systems, flat plate collectors, focusing collectors, solar water heating, solar cooling, solar distillation, solar refrigeration, solar dryers, solar pond, solar thermal power generation, photovoltaic systems, energy plantations, solar energy application in India

MODULE IV: Ocean and wind systems for energy production (9 hrs)

Ocean wave energy conversion, ocean thermal energy conversion: Open cycle and closed cycle thermal energy conversion system, tidal energy conversion, oscillating air column energy conversion, single basin single and double effect tidal energy conversion systems.

Wind energy, types of windmills, Types of wind rotors, Darrieus rotor and Savanius rotor, Wind electric power generation, wind power in India, economics of wind farm

MODULE V: Energy harnessing methods from biomass and geothermal resources (10 hrs)

Biomass energy resources, Thermo-chemical methods of biomass conversion, combustion, gasification, pyrolysis, Biochemical methods of biomass conversion: fermentation, anaerobic digestion

Geothermal energy resources: Types geothermal energy deposits, Hydro, geo, Petro geothermal resources and its harnessing methods. Types of geothermal power plant, working of steam geothermal power plant

Text books

1. Miller Bruce G., Coal Energy Systems, Elsevier Academic Press, Paris 2005
2. Rao S. &Parulekar B.B., Energy Technology, Khanna Publishers.
3. Twidel, J. and Tony W., Renewable Energy Resources, Second Edition, Taylor & Francis 2006
4. Kreith F., Goswami D.Y., Energy Management and Conservation, CRC Press 2008
5. Sukhatme S., J Nayak J., Solar Energy: Principles of thermal Collection and Storage, 3 rd Ed., Tata McGrow-Hill Pulishing Company Ltd. 2008
6. Mondal P and Dalai A., Sustainable utilization of natural resources, CRC Press 2017

Reference books

1. Dr. Prasenjit Mondal, Technologies for clean and renewable energy production, NPTEL course, IIT Kharagpur
2. Sukhatme S.P., Solar Energy, Tata McGraw Hill
3. Mittal K.M., Non-Conventional Energy Systems, Wheeler Publications
4. Venkataswarlu D.I, Chemical Technology, S. Chand
5. Pandey G.N., A Text Book on Energy System and Engineering, Vikas Publishing.
6. Rai G.D., Non-Conventional Energy Sources, Khanna Publishers.
7. S.S.Thipse, Energy conservation and management, Narosa Publishing House

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1	
1.1	Pre-treatment of coal- Desulphurization and demineralization	1
1.2	Pre-treatment of coal- Desulphurization and demineralization	1
1.3	Modification processes: Fluidized bed reactor, super critical boiler and flue gas clean up	1
1.4	Modification processes: Fluidized bed reactor, super critical boiler and flue gas clean up	1
1.5	Oxy-fuel combustion,	1
1.6	Chemical looping combustion	1
1.7	Chemical looping combustion	1
1.8	Gasification	1
1.9	Direct liquefaction	1
1.10	Underground coal gasification	1
	MODULE II	
2.1	Overview of Petroleum Crude	1

2.2	Environmental Impacts of Conventional Energy Production	1
2.3	Environmental Impacts of Conventional Energy Production	1
2.4	Thermal Depolymerization (TDP)	1
2.5	LNG	1
2.6	CNG	1
2.7	Hydrocracking	1
2.8	Hydrotreating Processes	1
2.9	Gasification for Syngas	1
2.10	Hydrogen Production	1
	MODULE III	
3.1	Solar thermal systems	1
3.2	flat plate collectors	1
3.3	focusing collectors	1
3.4	Solar water heating, solar cooling	1
3.5	Solar distillation, solar refrigeration, solar dryers	1
3.6	Solar pond, solar thermal power generation,	1
3.7	Photovoltaic systems	1
3.8	Energy plantation	1
3.9	Solar energy application in India	1
	MODULE IV	
4.1	Ocean wave energy conversion	1
4.2	Ocean thermal energy conversion: Open cycle and closed cycle thermal energy conversion system	1
4.3	Ocean thermal energy conversion: Open cycle and closed cycle thermal energy conversion system	1
4.4	Oscillating air column energy conversion, single basin single and double effect tidal energy conversion systems.	1
4.5	Oscillating air column energy conversion, single basin single and double effect tidal energy conversion systems.	1

4.6	Wind energy, types of windmills	1
4.7	Types of wind rotors, Darrieus rotor and Savanius rotor	1
4.8	Wind electric power generation	1
4.9	Wind power in India, economics of wind farm	1
MODULE V		
5.1	Thermo-chemical methods of biomass conversion	1
5.2	Combustion, gasification, pyrolysis	1
5.3	Biochemical methods of biomass conversion: fermentation, anaerobic digestion	1
5.4	Biochemical methods of biomass conversion: fermentation, anaerobic digestion	1
5.5	Biochemical methods of biomass conversion: fermentation, anaerobic digestion	1
5.6	Types geothermal energy deposits	1
5.7	Hydro, geo, Petro geothermal resources and its harnessing methods	1
5.8	Types of geothermal power plant, working of steam geothermal power plant	1
5.9	Working of steam geothermal power plant	1
5.10	Working of steam geothermal power plant	1

CO Assessment Sample Questions	
1	Explain any three advanced energy production methods from coal.
2	Describe the modes of clean energy production from crude petroleum.
3	Differentiate between flat plate collectors and focusing collectors
4	Discuss the different ocean energy conversion technologies and comment on their future scope
5	Analyze the process of biomass conversion technologies.

24CHH511	SOFT COMPUTING TECHNIQUES	L	T	P	J	S	C	Year of Introduction
		4	0	0	0	4	4	2024

Preamble: This course gives an introduction to some new fields in soft computing with its principal components of fuzzy logic, NN, GA and Fuzzy genetic hybrid systems.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Explain the concepts involved in fuzzy logic systems.
CO 2	Design fuzzy logic controllers for various applications
CO 3	Train neural networks for various applications
CO 4	Solve optimization problems using Genetic Algorithms
CO 5	Understand the concepts of Hybrid Soft computing techniques.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	3	3		3	3							3
CO 2	3	3		3	3							3
CO 3	3	3		3	3							3
CO 4	3	3		3	3							3
CO 5	3	3		3	3							3

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
4-0-0-0	5	5	10	10	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60

SYLLABUS

MODULE I : Introduction to fuzzy logic (10 hrs.)

Introduction to fuzzy logic: Fuzzy Sets-Fuzzy set operations-Fuzzy Relations
Cardinality of fuzzy relations-operations on Fuzzy Relations-Properties of Fuzzy relations-Properties of fuzzy relations-Membership functions-features of membership functions-Fuzzification-methods of membership value assignments-fuzzy rule base

MODULE II : Defuzzification (10 hrs.)

Defuzzification-Defuzzification methods-Fuzzy logic controller (Block diagram). Artificial neural networks. Basic concepts-Neural network architecture-Single layer feed forward network-Multilayer feed forward network-Recurrent networks

MODULE III : Neutral networks (10 hrs.)

Characteristics of Neural networks- Learning methods. Perceptron networks-Back propagation networks-Radial base function network-Hopfield network-Kohonenself-organising maps.

MODULE IV : Fundamentals of genetic algorithms (10 hrs.)

Fundamentals of genetic algorithms: Basic concepts-working principle-encoding-different methods-fitness function-reproduction-different methods. Genetic modelling- inheritance-cross over mutation-convergence of genetic algorithm.

MODULE V : Hybrid systems (8 hrs.)

Hybrid systems: Neural network, fuzzy logic and genetic algorithm hybrids-Neuro fuzzy
hybrids-neuro genetic hybrids-Fuzzy genetic hybrids.

Text books

1. S. Haykins, Neural networks a comprehensive foundation, Pearson Education.
2. L. Fausett, Fundamentals of Neural Networks, Prentice Hall 1994.
3. Timothy J Ross, Fuzzy Logic with Engineering Applications, McGrawHill, New York.

Reference books

1. S. N. Sivanandam, S. N. Deepa, Principles of Soft Computing, Wiley India Pvt. Ltd.
2. S. Rajasekharanand and G.A. VijayalakshmiPai, Neural Network, Fuzzy Logic and
3. Genetic Algorithms- Synthesis and Applications, Prentice Hall of India.
4. D.E. Goldberg, Genetic Algorithms in search Optimization and Machine Learning,
5. Pearson Education.
6. AmitKonar, Artificial Intelligence and Soft Computing, First Edition,CRC Press,
7. John Yen, Reza Lengari, Fuzzy Logic- Intelligence, Control and Information, Pearson Education.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1	
1.1	Introduction to fuzzy logic: Fuzzy Sets-Fuzzy set operations	1
1.2	Introduction to fuzzy logic: Fuzzy Sets-Fuzzy set operations	1
1.3	Fuzzy relations-Cardinality of fuzzy relations-operations on	1
1.4	Fuzzy Relations-Properties of Fuzzy relations-properties of fuzzy relations.	1
1.5	Fuzzy Relations-Properties of Fuzzy relations-properties of fuzzy relations.	1
1.6	Membership functions-features of membership functions	1
1.7	Membership functions-features of membership functions	1

1.8	Fuzzification-methods of membership value assignments-fuzzy rule base	1
1.9	Fuzzification-methods of membership value assignments-fuzzy rule base	1
MODULE II		
2.1	Defuzzification methods	1
2.2	Defuzzification methods	1
2.3	Fuzzy logic controller (Block diagram).	1
2.4	Fuzzy logic controller (Block diagram).	1
2.5	Artificial neural networks. Basic concepts	1
2.6	Artificial neural networks. Basic concepts	1
2.7	Neural network architecture-Single layer feed forward network-	1
2.8	Multilayer feed forward network-Recurrent networks	1
2.9	Multilayer feed forward network-Recurrent networks	1
MODULE III		
3.1	Characteristics of Neural networks- Learning methods.	1
3.2	Characteristics of Neural networks- Learning methods.	1
3.3	Perceptron networks-Back propagation networks	1
3.4	Perceptron networks-Back propagation networks	1
3.5	Perceptron networks-Back propagation networks	1
3.6	Radial base function network-Hopfield network	1
3.7	Radial base function network-Hopfield network	1
3.8	Radial base function network-Hopfield network	1

3.9	Kohonen self-organising maps	1
3.10	Kohonen self-organising maps	1
MODULE IV		
4.1	Fundamentals of genetic algorithms- Basic concepts- working principle	1
4.2	Fundamentals of genetic algorithms- Basic concepts- working principle	1
4.3	Encoding-different methods	1
4.4	Encoding-different methods	1
4.5	Fitness function-reproduction-different methods.	1
4.6	Fitness function-reproduction-different methods.	1
4.7	Fitness function-reproduction-different methods.	1
4.8	Genetic modelling-inheritance- crossover mutation-convergence of genetic algorithm.	1
4.9	Genetic modelling-inheritance- crossover mutation-convergence of genetic algorithm.	1
4.10	Genetic modelling-inheritance- crossover mutation-convergence of genetic algorithm.	1
MODULE V		
5.1	Hybrid systems: Neural network, fuzzy logic and genetic algorithm hybrids	1
5.2	Hybrid systems: Neural network, fuzzy logic and genetic algorithm hybrids	1
5.3	Hybrid systems: Neural network, fuzzy logic and genetic algorithm hybrids	1
5.4	Neuro fuzzy hybrids-neuro genetic hybrids	1
5.5	Neuro fuzzy hybrids-neuro genetic hybrids	1

5.6	Neuro fuzzy hybrids-neuro genetic hybrids	1
5.7	Fuzzy genetic hybrids.	1
5.8	Fuzzy genetic hybrids.	1

CO Assessment Sample Questions	
1	1. Explain the features of fuzzy membership functions with proper diagrams. 2. Discuss fuzzy equivalence relations and list out its properties?
	3. For the fuzzy sets A = {0.2/x1 + 0.9/x2} and B = {0.3/y1 + 0.5/ y2 + 1/y3}, find the fuzzy relation A×B
2	1. Defuzzify the following output membership function using centroid method: 0/0, 0.3/1, 0.3/3.5, 0.5/4, 0.5/5.5, 1/6, 1/7, 0/8. 2. Explain any five defuzzification methods.
3	List the stage involved in Back Propagation Algorithm?
4	Explain different types of Encoding Techniques.
5	Explain the characteristics and different classifications of a neuro-fuzzy hybrid system.

FIFTH SEMESTER
MINOR

24CHM509	HEAT AND MASS TRANSFER	L	T	P	J	S	C	Year of Introduction
		4	0	0	0		4	2024

Preamble: The objective of the course is to introduce the various modes of heat
transfer, conduction, convection and radiation and also the basics of mass transfer

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Apply principles of heat transfer to engineering problems
CO2	Analyse and obtain solutions to problems involving various modes of heat transfer
CO3	Explain laminar and turbulent boundary layers and ability to formulate energy equation in flow systems.
CO4	Apply principles of mass transfer to engineering problems

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	2								
CO2	3	3	3	2								
CO3	3	3	3	2								
CO4	3	3	3	2								

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course		Theory [L- T]	Tota

Structure [L-T-P-J]	Attendance	Assignment	Test-1	Test-2	l Marks
4-0-0-0	5	15	10	10	40

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 Hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I : Conduction

Modes of Heat Transfer: Conduction: Fourier law of heat conduction-Thermal conductivity of solids, liquids and gases- Factors affecting thermal conductivity- Most general heat conduction equation in Cartesian, cylindrical and spherical coordinates (no derivation required), One dimensional steady state conduction without heat generation conduction through plane walls, cylinders and spheres,
Critical radius of insulation.

MODULE II : Boundary layer and convection

Elementary ideas of hydrodynamics and thermal boundary layers-Thickness of Boundary layer-Displacement, Momentum and Energy thickness (description only).Convection heat transfer: Newton's law of cooling-Laminar and Turbulent flow, Reynolds Number, Critical Reynolds Number, Prandtl Number, Nusselt Number, Grashoff Number and Rayleigh's Number.
MODULE III : Radiation
Radiation- Nature of thermal radiation-definitions and concepts- monochromatic and total emissive power-Intensity of radiation- solid angle- absorptivity, reflectivity and transmissivity-Concept of black body-Planck' law- Kirchoff's law- Wein's displacement law-Stefan Boltzmann's law- black, gray and real surfaces-Configuration factor
MODULE IV : Introduction to mass transfer
Mass Transfer :Mass transfer by molecular diffusion- Fick's law of diffusion- diffusion coefficient Steady state diffusion of gases and liquids through solid- equimolar diffusion, Isothermal evaporation of water through air-simple problems.
MODULE V : Mass transfer coefficients
Convective mass transfer- Evaluation of mass transfer coefficient- empirical relations- simple problems- analogy between heat and mass transfer.
Text books 1. Sachdeva R C, Fundamentals of Engineering Heat and Mass Transfer, New Age Science Limited, 2009 2. R.K.Rajput. Heat and mass transfer, S.Chand & Co., 2015 3. Nag P K., Heat and Mass Transfer, McGraw Hill, 2011
Reference books 1. Yunus A Cengel, Heat Transfer: A Practical Approach, McGraw Hill,2015 2. Holman J P, Heat Transfer, McGraw Hill, 2011 3. Frank P. Incropera and David P. Dewitt, Heat and Mass Transfer, John Wiley and sons, 2011

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE 1 (9 hours)		
1.1	Modes of Heat Transfer	1
1.2	Fourier law of heat conduction-Thermal conductivity of solids, liquids and gases	1
1.3	Factors affecting thermal conductivity	1

1.4	Most general heat conduction equation in Cartesian, cylindrical and spherical coordinates	1
1.5	Most general heat conduction equation in Cartesian, cylindrical and spherical coordinates	1
1.6	One dimensional steady state conduction without heat generation conduction through plane walls, cylinders and spheres	1
1.7	One dimensional steady state conduction without heat generation conduction through plane walls, cylinders and spheres	1
1.8	Critical radius of insulation	1
1.9	Critical radius of insulation	1
MODULE II (10 hours)		
2.1	Hydrodynamics and thermal boundary layers	1
2.2	Hydrodynamics and thermal boundary layers	1
2.3	Thickness of Boundary layer-Displacement, Momentum and Energy thickness	1
2.4	Thickness of Boundary layer-Displacement, Momentum and Energy thickness	1
2.5	Newton's law of cooling- Laminar and Turbulent flow	1
2.6	Newton's law of cooling- Laminar and Turbulent flow	1
2.7	Reynolds Number, Critical Reynolds Number, Prandtl Number, Nusselt Number, Grashoff Number and Rayleigh's Number.	1
2.8	Reynolds Number, Critical Reynolds Number, Prandtl Number, Nusselt Number, Grashoff Number and Rayleigh's Number	1
2.9	Reynolds Number, Critical Reynolds Number, Prandtl Number, Nusselt Number, Grashoff Number and Rayleigh's Number	1
2.10	Reynolds Number, Critical Reynolds Number, Prandtl Number, Nusselt Number, Grashoff Number and Rayleigh's Number	1
MODULE III (11 hours)		
3.1	Radiation- Nature of thermal radiation-definitions and	1

	concepts	
3.2	Radiation- Nature of thermal radiation-definitions and concepts	1
3.3	Monochromatic and total emissive power-Intensity of radiation- solid angle	1
3.4	Monochromatic and total emissive power-Intensity of radiation- solid angle	1
3.5	Absorptivity, reflectivity and transmissivity-Concept of black body	1
3.6	Absorptivity, reflectivity and transmissivity-Concept of black body	1
3.7	Planck' law- Kirchoff's law- Wein's displacement law	1
3.8	Stefan Boltzmann's law- black, gray and real surfaces	1
3.9	Configuration factor	1
3.10	Configuration factor	1
3.11	Configuration factor	1
MODULE IV (8 hours)		
4.1	Mass Transfer :Mass transfer by molecular diffusion- Fick's law of diffusion	1
4.2	Mass Transfer :Mass transfer by molecular diffusion- Fick's law of diffusion	1
4.3	Diffusion coefficient, Steady state diffusion of gases and liquids through solid	1
4.4	Diffusion coefficient, Steady state diffusion of gases and liquids through solid	1
4.5	Diffusion coefficient, Steady state diffusion of gases and liquids through solid	1
4.6	Equimolar diffusion, Isothermal evaporation of water through air- simple problems	1
4.7	Equimolar diffusion, Isothermal evaporation of water through air- simple problems	1

4.8	Equimolar diffusion, Isothermal evaporation of water through air- simple problems	1
	MODULE V (10 hours)	
5.1	Convective mass transfer- Evaluation of mass transfer coefficient	1
5.2	Convective mass transfer- Evaluation of mass transfer coefficient	1
5.3	Convective mass transfer- Evaluation of mass transfer coefficient	1
5.4	Empirical relations	1
5.5	Empirical relations	1
5.6	Empirical relations	1
5.7	Simple problems- analogy between heat and mass transfer	1
5.8	Simple problems- analogy between heat and mass transfer	1
5.9	Simple problems- analogy between heat and mass transfer	1
5.10	Simple problems- analogy between heat and mass transfer	1

	CO Assessment Sample Questions
1	A furnace wall is made up of three layers of thicknesses 250 mm, 100 mm and 150 mm with thermal conductivities of 1.65 W/m.K and 9.2 W/m.K respectively. The inside is exposed to gases at 1250^{o}C with a convection coefficient of 25 W/m^2.K. and the inside surface is at 1100^{o}C, the outside surface is exposed to air at 25^{o}C with convection coefficient of 12 W/m^2.K. Determine (a) the unknown thermal conductivity K (b) the overall heat transfer coefficient (c) all the intermediate temperatures?
2	A hollow sphere (k = 65 W/m.K) of 120 mm inner diameter and 350 mm outer diameter is covered 10 mm layer of insulation (k =10 W/m.K). The inside and outside temperatures are 500 °C and 50 °C respectively. Calculate the rate of heat flow through this sphere.
3	Explain the boundary layer concept

4	Dry air at 300 ^0C and 1 atm flows over a wet flat plate 600 mm. long at a velocity of 50 m/s. Calculate the mass transfer coefficient of water vapour in air at the end of the plate. Take the diffusion coefficient of water vapour in air, D = 0.26 x 10 $^{-4}$ m^2/s.

SIXTH SEMESTER

24CHT601	HETEROGENEOUS CATALYSIS AND REACTOR DESIGN	L	T	P	J	S	C	Year of Introduction
		2	1	0	0	2	3	2024

Preamble: This course is meticulously crafted to provide students with a profound exploration of Chemical Reaction Engineering. The course is intended to familiarize the students with concepts of non-ideal flow, heterogeneous catalysis and design aspects of catalytic reactors and gas gas-liquid Reactors. By the end of the course the students will possess a comprehensive skill set and theoretical knowledge crucial for the analysis, and design of reactors in diverse chemical reaction engineering scenarios.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Determine conversion in real reactors using flow models and RTD information.
CO 2	Design chemical reactors for fluid particle non catalytic reactions.
CO 3	Develop rate laws and determine rate law parameters to design chemical reactors for solid catalytic reactions.
CO 4	Analyse the effect of diffusion process and reaction kinetics in porous catalyst system.
CO 5	Develop design equations for heterogeneous catalytic reactors.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	3	3	2									
CO 2	3	3	2									
CO 3	3	3	2									
CO 4	3	3										
CO 5	3	3	2									

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	**Attendance**	**Theory [L- T]**			**Total Marks**
		Assignment	**Test-1**	**Test-2**	
2-1-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3hrs

End Semester Examination [ESE]: Pattern			
PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I : Basics of non-ideal flow

Importance & interpretation of RTD, C, E & F curves & Statistical interpretation, Dispersion model. Tanks in series model, Conversion in non-ideal flow reactors for simple systems.

MODULE II : Non catalytic systems

Introduction to Fluid-Fluid reactions, Kinetics of straight mass transfer without reaction, Kinetics for direct mass transfer with the reaction for all types of reactions, the significance of Hatta Number and related problems on fluid-fluid reactions.

Introduction to Fluid-Particle reactions, selection of suitable model, Kinetics for different rate-controlling steps for spherical particles of unchanging size

and shrinking spherical particles, limitation of the shrinking core model, rate determining steps with a combination of resistances and related problems
MODULE III : Catalysis
Introduction to catalysis, Properties of catalysts, Estimation methods for catalytic properties, Promoters, Inhibitors etc., Mechanism of catalysis, Rate equations for different rate controlling steps.
MODULE IV : Solid Catalyzed Reactions
Rate equation for surface kinetics, heterogeneous systems, Pore diffusion resistance combined with surface kinetics, Thiele modulus and enhancement factor.

MODULE V : Performance equation for different reaction systems Performance equations for reactors containing porous catalyst particles, Experimental methods for finding rates, Packed bed catalytic reactor & reactors with suspended solid catalyst. Gas-liquid reactors: Trickle Bed, Slurry reactors. Three phase fluidized bed.
Text books 1. Octave Levenspiel, Chemical Reaction Engineering, 3rd Edition, John Wiley & Sons, 2001. 2. H. Scott Fogler, Elements of Chemical Reaction Engineering. 3rd Edition Prentice Hall,2001.
Reference books 1. J.M. Smith, Chemical Engineering Kinetics -3rd Edition, McGraw Hill., 1984 2. K.A. Gavhane, Chemical Reaction Engineering-I,series Volume-1 3. Nirali Prakashan., ISBN- 13: 9788185790879, 2011.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE 1 (6 hours)		
1.1	Importance & interpretation of RTD,	1
1.2	C, E & curves & Statistical interpretation.	1
1.3	C, E & curves & Statistical interpretation.	1
1.4	Dispersion mode.	1
1.5	Tanks in series model.	1
1.6	Conversion in non- ideal flow reactors for simple systems.	1
MODULE II (9 hours)		
2.1	Introduction to Fluid-Fluid reactions.	1
2.2	Kinetics of straight mass transfer without reaction.	1
2.3	Kinetics for direct mass transfer with the reaction for all types of reactions.	1

2.4	the significance of Hatta Number and related problems on fluid-fluid reactions.	1
2.5	Introduction to Fluid-Particle reactions, selection of suitable model.	1
2.6	Kinetics for different rate-controlling steps for spherical particles of unchanging size and shrinking spherical particles.	1
2.7	limitation of the shrinking core model.	1
2.8	rate determining steps with a combination of resistances and related problems.	1
2.9	rate determining steps with a combination of resistances and related problems.	1
	MODULE III (6 hours)	

3.2	Estimation methods for catalytic properties, Promoters, Inhibitors etc.	1
3.3	Mechanism of catalysis.	1
3.4	Mechanism of catalysis.	1
3.5	Rate equations for different rate controlling steps.	1
3.6	Rate equations for different rate controlling steps.	1
	MODULE IV (8 hours)	
4.1	Rate equation for surface kinetics.	1
4.2	Rate equation for surface kinetics, heterogeneous systems.	1
4.3	Pore diffusion resistance combined with surface kinetics.	1
4.4	Pore diffusion resistance combined with surface kinetics.	1
4.5	Pore diffusion resistance combined with surface kinetics.	1
4.6	Thiele modulus and enhancement factor.	1
4.7	Thiele modulus and enhancement factor.	1
4.8	Thiele modulus and enhancement factor.	1
	MODULE V (7 hours)	
5.1	Performance equations for reactors containing porous catalyst particles.	1
5.2	Experimental methods for finding rates.	1
5.3	Packed bed catalytic reactor & reactors with suspended solid catalyst.	1
5.4	Packed bed catalytic reactor & reactors with suspended solid catalyst.	1
5.5	Gas-liquid reactors: Trickle Bed, Slurry reactors. Three phase fluidized bed.	1

5.6	Gas-liquid reactors: Trickle Bed, Slurry reactors. Three phase fluidized bed.	1
5.7	Gas-liquid reactors: Trickle Bed, Slurry reactors. Three phase fluidized bed.	1

CO Assessment Sample Questions	
1	A Sample of tracer is injected as a pulse to a reactor and following C pulse versus time data is obtained. Tabulate E (t) and F (t) values.
2	Calculate the time required for complete burning of graphite (Size R0 =5mm, density =2.28g/cc) in an 8% oxygen stream at 900 0C and 1 atm. For high gas velocity assume that film diffusion does not offer any resistance to transfer and reaction. Rate constant k″=20 cm/s.

3	For the reaction $A+B \rightarrow C$, the mechanism is given by, A+ S → A.S adsorption B+ S → B.S A.S+ B.S → C.S +S surface reaction C.S → C+S. desorption Develop the overall rate equation assuming (a) adsorption of A as rate controlling (b) Surface reaction as rate controlling.
4	Obtain Thiele modulus from the derivation describing diffusion and reaction for A → B.
5	Determine the amount of catalyst needed in a packed bed reactor with a very large recycle rate (assume mixed flow) for 35 % conversion of A to R for a feed rate of 2000mol/hr of pure A at 3.2 atm and 117 ^{0}C. For the reaction at this temperature, A →4R, -rA'= 96 C_A, mol/Kg catalyst.hr.

T, min	1	3	5	7	9	11	13	15
C pulse, g/L	0	0	10	25	8	5	0	0

24CHP602	INSTRUMENTATION & PROCESS CONTROL	L	T	P	J	S	C	Year of Introduction
		2	0	2	0	4	3	2024

Preamble: Instrumentation and process control play a vital role in manufacturing, oil and gas, chemical, pharmaceuticals, and many others. The ability to monitor and control process variables like temperature, pressure, flow, and level ensures optimal operation, reduces downtime, minimizes waste, and enhances overall process efficiency. This course intends to provide a comprehensive understanding of instrumentation and process control principles, techniques, and devices. At the end of the course, the students will gain a solid foundation in the fundamental concepts and terminology of instrumentation and process control. The practice hours can be utilized to learn real-time dynamics and control of process parameters such as temperature, pressure, level, and concentration in simple basic systems.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to:

CO1	Categorize measuring instruments for industrial applications and illustrate instrumentation for temperature, and pressure.
CO2	Develop the transfer function of simple first-order systems, first-order systems in series, and second-order systems and predict the response of first and second-order systems.
CO3	Describe the components of a control system, develop its closed-loop transfer function, and predict the control action of P, PI, PD, and PID controllers.
CO4	Comment on the stability of control systems using the Root Locus method, frequency response method, and perform rudimentary controller tuning.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO 11	PO12
CO1	3	3										
CO2	3	3	2	2	2			2	2			2
CO3	3	3	2									
CO4	3	3	2	2	2			2	2			2

Assessment Pattern for Theory Component

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	√	√	√	√
Understand	√	√	√	√
Apply	√	√	√	√
Analyse			√	
Evaluate			√	

Create			√	

Assessment Pattern for Lab Component

Bloom's Category	Continuous Assessment Tools	
	Classwork	Test1
Remember		
Understand	√	√
Apply	√	√
Analyse	√	√
Evaluate	√	
Create	√	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Practical [P]		Total Marks
		Assignment	Test-1	Test-2	Class work	Lab Exam	
2-0-2-0	5	15	10	-	20	10	**60**

Total Marks distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	60	40	2.5 Hrs

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 2		2 questions will be given from each module, out of which1question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x 8 = 40 marks) Time: 2.5 hours	40
	Total Marks: 0	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Concept of Measurement

Measurement methods – Direct and Indirect methods. Functional elements – primary, secondary, manipulating element, data transferring element. Static characteristics – definition of accuracy, precision, repeatability, drift, sensitivity, dead zone, causes of dead zone, and static error. Dynamic characteristics – speed of response, time lag, dynamic error.

Sensors and Transducers, Data Acquisition – Overview. Temperature measurement: Electrical temperature sensor – thermocouples and thermistors. Pressure measurement: Principle, construction, and applications of Bourdon tube, ionization gauge, and McLeod gauge.

MODULE II: Laplace transforms and First Order systems

Laplace transforms - final value theorem - initial value theorem, inversion by partial fraction, solution of differential equations. Linear open loop systems - mercury thermometer, liquid level process – single tank system. Response for various input forcing functions.

MODULE III: Second-Order Systems

U-tube manometer – mathematical model and transfer function. Characteristics of a second order system, Step response of second order systems. Control valves- types, working principle, selection.

MODULE IV: Closed Loop Systems

P, PI, and PID Controllers - basic principles and transfer functions.
Closed loop systems – feedback control - servo and regulatory control problems - block diagram development – Block diagram reduction – Transient response of simple control systems – step response and offset.

MODULE V: Stability Analysis

Stability Analysis: Concept of BIBO stability and Asymptotic stability - Time response for various pole locations - stability of feedback systems - Routh - Hurwitz criterion for stability, Root locus technique - plotting root locus diagram, Frequency response analysis – Bode Diagram, Phase margin and Gain Margin, Ziegler – Nichols Controller tuning.

Textbooks

1. Jain R K, Mechanical and Industrial measurements, Khanna publishers
2. Patranabis D, Principles of Industrial Instrumentation, Tata-McGraw Hill.
3. Coughanewr D.P., Process Systems Analysis & Control, McGraw Hill
4. Stephanopoulos G., Chemical Process Control, An Introduction to Theory & Practice, Prentice Hall of India
5. Dale E. Seborg, Thomas F. Edgar and Duncan A. Mellichamp, Process Dynamics and Control, John Wiley & Sons Inc. Second Edition.

Reference books

1. Donald P Eckman, Industrial Instrumentation, CBS Publishers and Distributors, New Delhi
2. Eckman D.P., Principles of Industrial Process Control, John Wiley & Sons Inc, NY (1946)
3. Harriot P., Process Control, Tata McGraw Hill
4. Ceaglske N.H., Automatic Process Control for Chemical Engineers, John Wiley & Sons, NY, 1956

COURSE CONTENTS AND LECTURE SCHEDULE

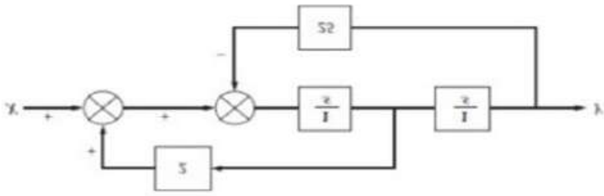
No.		No. of Hours
	MODULE 1 (5 Hours)	
1.1	Measurement methods – Direct and Indirect methods. Functional elements – primary, secondary, manipulating element, data transferring element.	1
1.2	Static characteristics – definition of accuracy, precision, repeatability, drift, sensitivity, dead zone, causes of dead zone, and static error. Dynamic characteristics – speed of response, time lag, dynamic error.	1
1.3	Sensors and Transducers, Data Acquisition - Overview	1
1.4	Temperature measurement: Electrical temperature sensor – thermocouples and thermistors	1
1.5	Pressure measurement: Principle, construction, and applications of Bourdon tube, ionization gauge, and McLeod gauge.	1
	MODULE II (5 Hours)	
2.1	Laplace transform - final value theorem - initial value theorem	1
2.2	inversion by partial fraction - solution of differential equations.	1
2.3	Linear open loop systems - mercury thermometer	1
2.4	Linear open loop systems - liquid level process – single tank system	1
2.5	Response of these systems for various input-forcing functions – step, ramp, impulse, and sinusoidal inputs.	1
	MODULE III (4 Hours)	
3.1	U-tube manometer – mathematical model and transfer function	1
3.2	Second-order system – characteristics and response toward step function	1
3.3	Second-order system – characteristics and response toward step	1

	function	
3.4	Control valves- types, working principle, selection	1
MODULE IV (5 Hours)		
4.1	P, PI, and PID Controllers - basic principles and transfer functions.	1
4.2	Closed loop systems – feedback control	1
4.3	servo and regulatory control problems	1
4.4	block diagram development and block diagram reduction	1
4.5	Transient response of simple control systems – step response and offset	1
MODULE V (5 Hours)		
5.1	Stability Analysis: Concept of BIBO stability and Asymptotic stability, Time response for various pole locations	1
5.2	stability of feedback systems - Routh - Hurwitz criterion for stability	1
5.3	Root locus technique - plotting root locus diagram.	1
5.4	Frequency analysis – Bode diagram, phase margin and gain margin	1
5.5	Zeigler – Nichol’s controller tuning	1

LESSON PLAN FOR LAB COMPONENT

No.	Topic	No. of Hours	Experiment
1	Linear open loop systems - mercury thermometer	2	Dynamic Response of Mercury in Glass Thermometer
2	U-tube Manometer	2	Dynamic Response of U-tube Manometer
3	Linear open-loop systems	2	Dynamics of Thermocouple
4	Linear open loop systems - liquid level process: single tank system	2	Dynamics of liquid level system - Single tank
5	Interacting and non-interacting types	2	Dynamics of liquid level system - non-interacting tanks in series
6	Interacting and non-interacting types	2	Dynamics of liquid level system - Interacting tanks in series
7	Linear open loop systems - mercury thermometer	2	Dynamic Response of Thermometer in Thermowell
8	P, PI, and PID Controllers - basic principles and transfer functions.	2	Level Control Trainer – study of proportional, PI, PD, and PID controllers
9	P, PI, and PID Controllers - basic principles and transfer functions.	2	Pressure Control Trainer – study of proportional, PI, PD, and PID controllers
10	Closed-loop system	2	Valve Characteristics
11	stability of feedback systems	2	Plotting root locus and bode diagram using MATLAB-Simulink / Scilab-Xcos
12	stability of feedback systems	2	Control system design using MATLAB-Simulink / Scilab-Xcos

CO Assessment Sample Questions	
1	Suggest a method for the measurement of pressure above 10,000kg/cm^2. Write its working principle
2	Find the final value of y(t) for the transfer function $$y(s) = \frac{1}{s(s^3 + 3s^2 + 3s + 1)}$$

3	Derive the transfer function Y/X for the control system shown in the figure given below 
4	Determine the stability of the characteristic equation by the Routh test. $2s4 + s3 + 3s2 + 4s + 10 = 0$

24CHP603	MASS TRANSFER OPERATIONS - II	L	T	P	J	S	C	Year of Introduction
		2	0	2	0	4	3	2024

Preamble: Objective of this course is to impart fundamental concepts of separation processes such as extraction, leaching, membrane separation, adsorption, humidification, drying and crystallization used in process industries. This course also helps students to quantify, formulate, and solve engineering problems involving different mass transfer operations through theoretical as well as practical approach.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Calculate the design parameters of extraction and leaching processes.
CO2	Select suitable membrane modules for separation processes.
CO3	Apply fundamental adsorption isotherms for the separation process.
CO4	Determine the humidification parameters using a psychrometric chart.
CO5	Calculate the design variables in drying and crystallization systems.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3					3	3	3		2
CO2	3	3	3									2
CO3	3	3	3			3		3	3	3		2
CO4	3	3	3					3	3	3		2
CO5	3	3	3					3	3	3		2

Assessment Pattern for Theory Component

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✓	✓	✓	✓
Understand	✓	✓	✓	✓

Apply	✓	✓	✓	✓
Analyse			✓	
Evaluate			✓	
Create				

Assessment Pattern for Lab component		
Bloom's Category	**Continuous Assessment Tools**	
	Class work	**Test1**
Remember		
Understand	√	√
Apply	√	√
Analyse	√	√
Evaluate	√	
Create	√	

Mark Distribution of CIA

Course Structure [L-T-P-J]	**Attendance**	**Theory [L- T]**			**Practical [P]**		**Total Marks**
		Assignment	**Test-1**	**Test-2**	**Class work**	**Lab Exam**	
2-0-2-0	5	15	10	-	20	10	60

Total Marks distribution

Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	60	40	2.5 Hours

End Semester Examination [ESE]: Pattern

PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 2		2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x 8 = 40 marks) Time: 2.5 hours	40
	Total Marks:	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Liquid-Liquid Extraction and purification

Extraction –applications, ternary equilibria on triangular coordinate system, mixer rule, distribution curve, selectivity, choice of solvent. Single-stage and multistage extraction operations - Calculations for immiscible systems and partially miscible systems. Construction and working of mixer -settler cascades, sieve-tray columns, agitated towers, pulse columns and centrifugal extractors.

MODULE II: Leaching and Membrane separation

Leaching – Rate of leaching, factors affecting rate of leaching. Working principles of leaching equipment- Shank's system- thickeners, classifiers and moving bed leaching equipment. Leaching equilibrium - constant underflow - variable underflow Single stage and multistage leaching.

Membrane separation processes – classification – types of membranes: flat, spiral wound, hollow fibre -concentration polarization – ultrafiltration.

MODULE III: Adsorption Operations

Adsorption, types of adsorptions, properties of adsorbents, adsorption isotherm for single gases, Vapours and dilute liquid solutions, Adsorption isotherms – Freundlich and Langmuir, Fixed bed adsorption, adsorption wave, rate of adsorption and breakthrough curve.

MODULE IV: Humidification

Humidification and dehumidification, use of humidity chart to find properties of air, Lewis relation, water cooling with air, types of cooling towers, Design of cooling tower, spray chambers for air humidification, principles of gas dehumidification.

MODULE V: Drying and Crystallization Operations

Drying, equilibrium, bound and unbound moisture content, batch drying, rate of drying, mechanism of moisture movement, continuous drying, parallel and counter current, material and enthalpy balances, classification of industrial dryers for batch and continuous drying.

Principles of crystallization, purity, yield, energy requirements, supersaturation, nucleation-primary and secondary nucleation, growth of crystals-delta –L law.

Text books

1. Treybal R.E., Mass Transfer Operations, McGraw Hill.
2. Binay K Dutta, Principles of Mass Transfer & Separation Processes, PHI Learning Private Limited.

Reference books

1. K.V. Narayanan and B. Lakshmikutty. Mass Transfer-Theory and Applications, CBS Publishers.
2. N. Anantharaman and K.M.Meera Sheriffa Begum, Mass Transfer-Theory and Practice, PHI Learning Private Limited (2011) New Delhi.
3. Welty J.R., Wilson R.E. & Wicks C.E., Fundamentals of Momentum Heat and Mass Transfer, John Wiley.
4. Foust A.S. et. al., Principles of Unit Operations, John Wiley.
5. McCabe W.L., Smith J.C. & Harriot P., Unit Operations in Chemical Engineering, McGraw Hill.
6. Seader J.D.& Henley E.J Separation Process Principles, John Wiley & Sons.
7. Coulson J.M. & Richardson J.F., Chemical Engineering, Vol. II, ELBS, Pergamon.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1 (5 hours)	
1.1	Extraction –applications, ternary equilibria on triangular coordinate system.	1
1.2	Mixer rule, distribution curve, selectivity, choice of solvent	1
1.3	Single-stage and multistage extraction operations - Calculations for immiscible systems and partially miscible systems.	1
1.4	Construction and working of mixer -settler cascades, sieve-tray columns	1
1.5	Agitated towers, pulse columns and centrifugal extractors.	1
	MODULE II (5 hours)	
2.1	Leaching – Rate of leaching, factors affecting rate of leaching. Working principles of leaching equipment- Shank's system-	1
2.2	thickeners, classifiers and moving bed leaching equipment. Leaching equilibrium - constant underflow.	1
2.3	Variable underflow Single stage and multistage leaching.	1
2.4	Membrane separation processes – classification – types of membranes: flat, spiral wound, hollow fibre.	1
2.5	concentration polarization – ultrafiltration.	1

MODULE III (4 hours)		
3.1	Adsorption, types of adsorptions, properties of adsorbents.	1
3.2	adsorption isotherm for single gases, vapours and dilute liquid solutions.	1
3.3	Adsorption isotherms –Freundlich and Langmuir	1
3.4	Fixed bed adsorption, adsorption wave, rate of adsorption and breakthrough curve.	1
MODULE IV (5 hours)		
4.1	Humidification and dehumidification, use of humidity chart to find properties of air	1
4.2	Lewis relation, water cooling with air, types of cooling towers	1
4.3	Design of cooling tower.	1
4.4	Spray chambers for air humidification.	1
4.5	Principles of gas dehumidification.	1
MODULE V (5 hours)		
5.1	Drying, equilibrium, bound and unbound moisture content,batch drying, rate of drying	1
5.2	mechanism of moisture movement, continuous drying, parallel and counter-current, material and enthalpy balances	1
5.3	classification of industrial dryers for batch and continuous drying.	1
5.4	Principles of crystallization, purity, yield, energy requirements, supersaturation.	1
5.5	nucleation-primary and secondary nucleation, growth of crystals-delta –L law.	1

LESSON PLAN FOR LAB COMPONENT

No.	Topic	No. of Hours	Experiment
1	Diffusivity and estimation - steady state diffusion of A through stagnant B	2	Diffusion coefficient measurement
2	Gas absorption - Solubility of gases in liquid	2	Absorption in Packed bed columns
3	Distillation	2	Simple Distillation
4	Distillation	2	Steam Distillation

5	Liquid-Liquid Extraction	2	Liquid extraction: Determination of ternary liquid – liquid equilibria
6	Leaching	2	Simple Leaching: varying number of stages Simple Leaching: varying solvent to feed ratio
7	Leaching	2	Counter current leaching
8	Leaching	2	Cross current leaching
9	Adsorption	2	Adsorption: Determination of adsorption isotherm.
10	Drying	2	Rotary Dryer

CO Assessment Sample Questions

1. A vegetable seed material containing 0.4 kg oil/kg insoluble solid is washed with hydrocarbon solvent in order to recover 90 % of the oil in a counter current unit. It is found that the under flow varies with the concentration of classifier as given below:

Amount of solution in under flow, (**kg solution/ kg insoluble solid**)	0.3	0.32	0.34	0.36	0.36	0.4
Concentration of solute in solution, (**kg solute/kg solution**)	0	0.1	0.2	0.3	0.4	0.5

If the solvent input flow 0.5 kg/kg insoluble solid, find the number of stages required.

2. Explain the suitability of various membrane modules used for the desalination operation. Compare the following membrane separations with suitable examples. (i) Reverse Osmosis, and (ii) Pervaporation

3. The following laboratory data were collected in a batch adsorption study. Plot the data according to Freundlich Isotherm and determine the values for the constants n and K_F. A volume of 500 mL is placed in each flask, and the waste has an initial COD of 100 mg/L.

Flask No.	Mass of C (mg)	Volume in Flask (mL)	Final COD (mg C/L)
1	965	500	3.5
2	740	500	5.2

		3	548	500	8.0	
		4	398	500	12.5	
		5	265	500	20.5	
		6	168	500	33	
		7	0	500	100	
4	Air at 303 K and with 75 % saturation is to be prepared from a supply of warm summer air at 310.7 K and 35 % humidity. This is achieved by spraying water to the inlet air and by heating the saturated air leaving the spray chamber to 303 K. Assume all the operations are atmospheric pressure. Using the psychrometric chart, determine the following: (i) The temperature of the air leaving the chamber. (ii) The amount of water evaporated per 1000 m^3 of air entering the chamber.					
5	Calculate the yield of $MgSO_4.7H_2O$ crystals when 1000 kg saturated solution of $MgSO_4$ at 353 K is cooled to 303 K assuming 10 % of the water is lost by evaporation during cooling. Data: Solubility of $MgSO_4$ at 353 K = 64.2 kg/100 kg water. Solubility of $MgSO_4$ at 303 k = 40.8 kg/100 kg water. Atomic Weight: Mg = 24, S = 32.					

24CHS606	SEMINAR	L	T	P	J	S	C	Year of Introduction
		0	0	4	0	4	2	2024

Preamble: The course 'Seminar' is intended to enable a B.Tech graduate to read, understand, present and prepare report about an academic document. This course can help the learner to experience how a presentation can be made about a selected academic document and also empower her/him to prepare a technical report.

Course Outcomes: After the completion of the course the student will be able to

CO1	Identify academic documents from the literature which are related to her/his areas of interest.
CO2	Apprehend an academic document from the literature which is related to her/his areas of interest.
CO3	Prepare a presentation on a selected topic.
CO4	Give a presentation about an academic topic.
CO5	Prepare a technical report.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	2	2	1	1		2	1					3
CO 2	3	3	2	3		2	1					3
CO 3	3	2			3			1		3		3
CO 4	3				2			1		3		3
CO 5	3	3	3	3	2	2		2		3		3

General Guidelines

1. The Department shall form an Internal Evaluation Committee (IEC) consisting of three senior faculty members.
2. Choosing a seminar topic: The topic for a UG seminar should be current and broad based rather than a very specific research work. It's advisable to choose a topic for the Seminar to be closely linked to the final year project area.
3. Topic/Paper shall be finalized in the first week of the semester and shall be submitted to the IEC. The IEC shall approve the selected topic/paper by the second week of the semester.

Evaluation pattern

The report and the presentation shall be evaluated by a team of internal members comprising three senior faculty members based on the style of presentation, technical content, adequacy of reference, depth of knowledge and overall quality of the report.

a) Attendance: 5%
b) Guide: 25%
c) Technical Content: 30%
d) Presentation: 40%

24SPJ607	SOCIALLY RELEVANT PROJECT	L	T	P	J	S	C	Year of Introduction
		0	0	0	2	1	1	2024

Preamble: The main purpose of Socially Relevant Projects is to make students understand their social commitments through projects which benefits both the institution as well as the society. The community will benefit from the focused contribution of students towards local development, and at the same time, the institution provides an opportunity for students to develop social sensibility and responsibility. After the completion of the course, the students will be able to think critically and creatively about social issues, and to develop innovative solutions to address them.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Identify socially relevant problems.
CO2	Analyse the problems using surveys and research.
CO3	Suggest technical solutions to the identified problems using relevant state of the art technologies.
CO4	Prepare a technical report.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1									3			2
CO2	2	2		3					3			2
CO3	3	2		2				3	3	3		2
CO4								3	2	3		2

Assessment Pattern

Bloom's Category	Continuous assessment tools	
	Evaluation 1	Evaluation 2
Remember		
Understand		
Apply	□	□
Analyse	□	□
Evaluate	□	□
Create	□	□

Mark Distribution of CIA						
Course Structure [L-T-P-J]	**Log book**	**Final Evaluation [MC]**			**Report**	**Total Marks**
0-0-0-2	**25**	**Objectives**	**Execution Process**	**Presentation**		
		10	**25**	**15**	**25**	**100**

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	100	-	-

General guidelines

- **Activities for Socially Relevant Project**

Conducting surveys and research on social issues and concerns to gain a better understanding of the problem and identify potential solutions.

Developing and implementing educational programs to promote awareness and understanding of social issues and concerns.

Collaborating with local NGOs and community groups to organize events and activities that promote social welfare and community development.

❖ Developing and implementing social welfare programs that address the needs of marginalized and vulnerable communities, such as homeless individuals, refugees, and low-income families.

❖ Conducting community service activities, such as volunteering at local shelters, food banks, and community centers.

❖ Developing and implementing environmental conservation programs that promote sustainable practices and reduce the impact of human activities on the environment.

❖ Creating and distributing educational materials, such as pamphlets and brochures, to raise awareness about social issues and concerns.

❖ Organizing fund raising events to support social welfare programs and community development initiatives.

❖ Engaging in advocacy and lobbying efforts to influence public policy and promote social justice.

- **Implementation of Socially Relevant Project**
- Each student should complete a minimum of 60 hours of community service during their lower semesters (1-5).
- Assign a group of students or a single student to a particular habitation, village, or municipal ward in the near vicinity of their place of stay.

Each team should be assigned with a mentor to guide them through the process. The project can be any socially prevailing issue related to water and sanitation, environment, energy, ecology, health care, housing, differently abled, irrigation, disaster management, mines and geology, agriculture, sustainability, heritage,,educational and entrepreneurship etc.

Each student shall keep a log book of their activities, which must be signed by their mentor or faculty member in charge.

❖ The participation of students in NSS/NCC/Club activities will not be coming under the purview of socially relevant projects.

❖ Each team shall submit a report and make a brief presentation based on the service rendered to the society, and an evaluation will be conducted by a committee constituted by the Head of the Department.

Procedure for doing Socially Relevant Project

❖ Conduct a survey of the habitation to gain a better understanding of the social issues and concerns that need to be addressed. A common survey format could be designed to ensure consistency.

❖ Develop a project work related to the student's domain or subject area that addresses the identified social issues and concerns. The project should be designed to be socially relevant and have a positive impact on the community.

❖ Implement the project work with the help of the local community and relevant authorities. This could include organizing awareness programs, developing and implementing educational programs, conducting community service activities, and engaging in advocacy and lobbying efforts.

❖ Monitor and evaluate the project work to ensure that it is having the desired impact on the community. This could include conducting surveys and research, gathering feedback from the local community, and tracking key performance indicators.

❖ Document the project work and its impact on the community, and share the findings with relevant stakeholders, including Each student shall keep a log book of their activities, which must be signed by their mentor or faculty member in charge.

❖ The participation of students in NSS/NCC/Club activities will not be coming under the purview of socially relevant projects.

❖ Each team shall submit a report and make a brief presentation based on the service rendered to the society, and an evaluation will be conducted by a committee constituted by the Head of the Department.

- **Procedure for doing Socially Relevant Project**

❖ Conduct a survey of the habitation to gain a better understanding of the social issues and concerns that need to be addressed. A common survey format could be designed to ensure consistency.

❖ Develop a project work related to the student's domain or subject area that addresses the identified social issues and concerns. The project should be designed to be socially relevant and have a positive impact on the community.

❖ Implement the project work with the help of the local community and relevant authorities. This could include organizing awareness programs, developing and implementing educational programs, conducting community service activities, and engaging in advocacy and lobbying efforts.

❖ Monitor and evaluate the project work to ensure that it is having the desired impact on the community. This could include conducting surveys and research, gathering feedback from the local community, and tracking key performance indicators.

❖ Document the project work and its impact on the community, and share the findings with relevant stakeholders, including the local community, government authorities, and academic institutions.

- **Time frame for the socially relevant project**
- Duration: 8 weeks
- Schedule:
- Socio-Economic Survey of the village / habitation (Two weeks): A group of students under the guidance of faculty mentors conduct a socio-economic survey of the village / habitation. They will interact with people to acquire basic knowledge on the project to be chosen for study and conduct the survey using a structured questionnaire.
- Community awareness campaign (One week): The student group takes up community awareness campaigns based on the above survey conducted by identifying the problems or vulnerable issues. They may also conduct house-to- house campaign on socially relevant theme. Eg: Government welfare programs, health care, consumer protection, food adulteration, digital transactions, information sources etc.
  - Main project (4 weeks): A group of students chose a topic related to their subject area and conduct a project which includes data collection interviews, internship in any selected unit or department and suggesting solution for the problem identified.

- Report preparation (1 week): The student should submit a project report duly signed by the mentor.

- **Evaluation pattern**
  - ❖ There will be only internal evaluation for this project.
  - Each faculty member is to be assigned with a group of five students. The faculty member will act as a faculty mentor for the group and is in charge for the learning activities of the students and also for the comprehensive and continuous assessments of the students.
  - The assessment is to be conducted for 100 marks. The weightage shall be:
    - Project log book: 25%
    - Project implementation: 50%
      (10% for objectives, 25% for execution/proposal and 15% for presentation).
    - Project report: 25%
  - While grading the student's performance using the student's project log, the following should be taken into account:
    - Individual student's effort and commitment.
    - Originality and quality of the work produced by the individual student.
    - Integration and co-operation with the work assigned.
    - The completeness of the log book.
  - Assessment for project implementation:
    - Orientation to the community development.
    - Conducting a baseline assessment of development needs.
    - Number of awareness programs and participants for each.
    - Number of intervention programs and participants for each.
    - Number of follow-up programs and participants for each.
    - Developing short-term and mid-term action plans in consultation with local leadership and local government officers.
  - Assessment for project presentation:
    - Assessing the involvement in the project.
    - Presentation skills.
    - Final outcome of the project.
  - Assessment for project report.

Note: Final Evaluation of the project should be done by a three-member Committee -
(Mentor shall be one member in the CIE committee).

Particulars	Percentage Contribution of total marks
Work assessed by the Mentor based on log book	25
Final evaluation by the Internal Three- member Committee [Split up is given below]	50
a. Establishing the Social relevance o f work (Objectives)	20
b. Illustrating the execution process for the attainment of outcome	50
c. Presentation	30
Final Report	25

24ESP609	ARTIFICIAL INTELLIGENCE IN CHEMICAL ENGINEERING	L	T	P	J	S	C	Year of Introduction
		1	0	2	0	3	2	2024

Preamble: In the context of increasing applications of data analytics in the process industry, the objective of this course is to introduce tools, methods, and frameworks to students. On successful completion of the course, students will be able master various technics that will be useful for analyzing raw process data into knowledge and to decision enabling information.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Explain data analysis and visualization.
CO 2	Explain the steps involved in implementing Principal Component Analysis.
CO 3	Apply clustering techniques.
CO 4	Utilize nonlinear approaches for effective process data analysis.
CO 5	Apply various model learning approaches.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	3	2			2							2
CO 2	3	2			2							2
CO 3	3	2			2							2
CO 4	3	2			2							2
CO 5	3	2			2							2

Assessment Pattern for Theory component

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	□	□	□	□
Understand	□	□	□	□
Apply	□	□	□	□
Analyse			□	
Evaluate			□	
Create			□	

Assessment Pattern for Lab component

Bloom's Category	Continuous Assessment Tools	
	Class work	Test1
Remember		
Understand	□	□
Apply	□	□

Analyse	□	□
Evaluate	□	
Create	□	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Practical [P]		Total Marks
		Assignment	Test-1	Test-2	Class work	Lab Exam	
1-0-2-0	5	10	20	-	25	40	**100**

Total Marks distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	100	-	-

SYLLABUS

MODULE I: Introduction to data analysis and visualization

Process data pre-processing, handling and regression Data error types: systematic errors, random errors, outliers; Data transformation; Data visualizations: histogram, heat map, tree map, scatter plots, spectral plots,regression models.

MODULE I: Advanced Techniques in Process Data Analysis

Dimensionality reduction and latent variable models with applications to fault detection and inferential modeling of processes Principal component analysis, factor analysis, canonical correlation analysis, partial least squares Classification with applications to process mode diagnosis k-nearest neighbour, naive Bayes, linear discriminants, support vector machine, decision trees and forests.

MODULE III: Advanced Process Mode Diagnosis

Clustering with applications to process mode diagnosis k-means, fuzzy c-means, possibilistic c-means, hierarchical clustering methods, mixture models.

MODULE IV: Nonlinear Approaches and Entropy in Process Data Analysis

Overview of nonlinear approaches Kernel methods-kernel PCA, kernel SVM, neural nets-feed forward networks, Gaussian process A brief introduction to entropy and its applications to redundant process variable isolation: Shannon entropy, cross entropy, joint and conditional entropy, KL- divergence, mutual information

MODULE V:Advanced Model Learning Techniques
Model learning approaches Maximum likelihood, maximum a posteriori, Bayesian approaches; Expectation-Maximization- application to mixture models, back propagation- application to neural nets, ensemble learning: bootstrapping methods- application to decision trees, Model assessment and validation: BIC, k-fold cross validation, concept of model averaging
Text books 1. Bishop, C., “Pattern Recognition and Machine Learning”, Springer, 2008. Murphy, K., “Machine Learning: A Probabilistic Perspective”, MIT Press, 2012. 2. Duda, R.O., Hart, P. E., and Stork, D.G., “Pattern Classification”, John Wiley & Sons, 2005.
Reference books 1. Hastie, T., Robert Tibshirani, R., and Friedman, J., “The Elements of Statistical Learning: 2. Data Mining, Inference, and Prediction”, Springer, 2009. 3. Runkler, T. A.,“Data Analytics Models and Algorithms for Intelligent Data Analysis”, Springer, 2012 4. Also relevant research papers pertaining to the application of theory to chemical process systems.

COURSE CONTENTS AND LECTURE SCHEDULE		
No.		No. of Hours
	MODULE 1 (5 hours)	
1.1	Process Data Pre-Processing.	1
1.2	Handling And Regression Data Error Types.	1
1.3	Systematic Errors, Random Errors, Outliers.	1
1.4	Data Transformation; Data Visualizations.	1

1.5	Histogram, Heat Map, Tree Map, Scatter Plots, Spectral Plots, Regression Models.	1
MODULE II (6 hours)		
2.1	Dimensionality Reduction And Latent Variable Models With Applications To Fault Detection and Inferential Modeling Of Processes Principal Component Analysis.	1
2.2	Dimensionality Reduction And Latent Variable Models With Applications To Fault Detection And Inferential Modeling Of Processes Principal Component Analysis.	1
2.3	Dimensionality Reduction And Latent Variable Models With Applications To Fault Detection And Inferential Modeling Of Processes Principal Component Analysis,	1
2.4	Dimensionality Reduction And Latent Variable Models With Applications To Fault Detection And Inferential Modeling Of Processes Principal Component Analysis,	1
2.5	Canonical Correlation Analysis, Partial Least Squares, Classification With Applications To Process Mode Diagnosis K-Nearest Neighbor.	1
2.6	Naive Bayes, Linear Discriminants, Decision Trees And Forests.	
MODULE III (4 hours)		
3.1	Clustering With Applications To Process Mode Diagnosis K-Means.	1
3.2	Clustering With Applications To Process Mode Diagnosis K-Means.	1
3.3	Fuzzy C-Means, Possibilistic C-Means, Hierarchical Clustering Methods, Mixture Models.	1
3.4	Fuzzy C-Means, Possibilistic C-Means, Hierarchical Clustering Methods, Mixture Models.	1
MODULE IV (4 hours)		

4.1	Overview Of Nonlinear Approaches Kernel Methods-Kernel PCA, Kernel SVM, Neural Nets-Feed Forward Networks.	1
4.2	Overview Of Nonlinear Approaches Kernel Methods-Kernel PCA, Kernel SVM, Neural Nets-Feed Forward Networks.	1
4.3	Overview Of Nonlinear Approaches Kernel Methods-Kernel PCA, Kernel SVM, Neural Nets-Feed Forward Networks.	1
4.4	A Brief Introduction To Entropy And Its Applications To Redundant Process Variable Isolation.	1
MODULE V (5 hours)		
5.1	Model Learning Approaches Maximum Likelihood, Maximum A Posteriori, Bayesian Approaches.	1
5.2	Expectation-Maximization- Application To Mixture Models, Back Propagation-Application To Neural Nets.	1
5.3	Ensemble Learning: Bootstrapping Methods.	1
5.4	Application To Decision Trees.	1
5.5	Model Assessment And Validation: BIC, K-Fold Cross Validation, Concept Of Model Averaging.	1

LESSON PLAN FOR LAB COMPONENT

No.	Topic	No. of	Experiment
1	Data Analysis Pipeline	1	Data Analysis Mastery Lab: Unveiling Patterns through Pre-processing, Erro
2	Data Analysis Pipeline	1	
3	Dimensionality Reduction and Fault Detection	1	Unveiling Patterns through Dimensionality Reductio
4	process mode diagnosis	1	Process Mode Diagnosis through Clustering
5	Kernel methods and neural networks,	1	

6	Entropy-based methods for isolating redundant process variables	1	Exploring Nonlinear Approaches

CO Assessment Sample Questions	
1	Explain the significance of data pre-processing in the context of regression analysis.
2	Discuss the role of principal component analysis (PCA) in dimensionality reduction for process data.
3	Demonstrate your understanding of clustering algorithms by explaining the key steps involved in implementing k-means and hierarchical clustering for process mode diagnosis.
4	Describe your understanding of nonlinear approaches by explaining the key steps involved in implementing kernel PCA and kernel SVM for process data analysis.
5	Detail the significance of model assessment and validation, outlining the steps involved in k-fold cross-validation and the concept of model averaging in improving predictive performance.

SIXTH SEMESTER

PROFESSIONAL ELECTIVE-1

		L	T	P	J	S	C	Year of Introduction
24CHE614	**AIR POLLUTIO MONITORING AND CONTROL**	**3**	**0**	**0**	**0**	**3**	**3**	**2024**

Preamble: This course is introduced to understand the atmospheric pollutant's standards, regulations, emission sources and their fate. The course deals with the fundamentals of atmospheric stability, air pollutant transport, characteristics of emission source and their control methods. It also gives an overview of indoor air pollution sources and its remedial methods to control and develop indoor air quality profile.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Define the sources, classifications and effects of air pollutants.
CO 2	Describe the ambient air quality standards as well as sampling and analysis of air pollutants from emission sources.
CO 3	Summarize the concepts of atmospheric dispersion characteristics and nature based on lapse rate and inversion.
CO 4	Design equipments to control particulates and gaseous pollutants.
CO 5	Explain the indoor air pollution sources, measurements, standards and control methods.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3				3	3					3
CO 2	3	3				3	3	3				3
CO 3	3	3					3					2
CO 4	3	3	3				3	3				2
CO 5	3	3					3					3

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	□	□	□	□
Understand	□	□	□	□
Apply	□	□	□	□
Analyse			□	
Evaluate			□	
Create			□	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	**40**

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 Hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Air Quality, Regulations and Effect

Structure and composition of Atmosphere – Definition, Scope and Scales of Air Pollution- Sources and classification of air pollutants-Effect on human health, vegetation, animals, property, aesthetic value and visibility- Ambient Air Quality and Emission standards–Ambient and stack sampling and Analysis of Particulate and Gaseous Pollutants. Air quality sensors.
MODULE II: Atmospheric Dispersion of Air Pollutant
Effects of meteorology on Air Pollution - Fundamentals, Atmospheric stability- Dry adiabatic lapse rate derivation, Inversion, Wind profiles and stack plume patterns- Atmospheric Diffusion Theories– Dispersion models, Plume Rise- Numerical Problems.
MODULE III: Control of Particulate Contaminants

Gas Particle Interaction – Working principle, Design and performance equations of Gravity Separators, Centrifugal separators, Fabric filters, Particulate Scrubbers, Electrostatic Precipitators–Operational Considerations- Factors affecting Selection of Control Equipment.
MODULE IV: Control of Gaseous Contaminants
Working principle, design and performance equations of absorption, Adsorption, condensation, Incineration, Bio scrubbers, Venturi scrubber- Bio filters – Process control and Monitoring –Operational Considerations- Factors affecting Selection of Control Equipment–CO_2 capturing, Hydrocarbon removal.
MODULE V: Indoor Air Quality Management
Sources types and control of indoor air pollutants, sick building syndrome types – HVAC system, IAQ issues and impacts on occupants—Developing an IAQ profile-Diagnose IAQ problem, Control-Quantification and Measurement.
Text books 1. Lawrence K. Wang, Norman C. Pareira, Yung Tse Hung, Air Pollution Control Engineering, Tokyo, 2004. 2. Noel de Nevers, Air Pollution Control Engineering, Mc Graw Hill, New York, 1995. 3. Nicholas P. Cheremisinoff, Handbook of Air Pollution Prevention and Control, Butterworth and Heinemann, Elsevier Science (USA), 2002.

Reference books

1. C. S. Rao, Environmental Pollution Control Engineering, Wiley Eastern Ltd, Delhi.
2. Anjaneyulu. Y, Air Pollution and Control Technologies, Allied Publishers (P) Ltd., India, 2002.
3. David H.F. Liu, Bela G. Liptak, Air Pollution, Lweis Publishers, 2000.
4. Arthur C.Stern, Air Pollution (Vol.I – Vol.VIII), Academic Press, 2006.
5. Wayne T.Davis, Air Pollution Engineering Manual , John Wiley & Sons, Inc., 2000.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1 (7 Hours)	
1.1	Structure and composition of Atmosphere – Definition, Scope and Scales of Air Pollution	1
1.2	Sources and classification of air pollutants	1
1.3	Effect on human health, vegetation, animals, property, aesthetic value and visibility	1
1.4	Effect on human health, vegetation, animals, property, aesthetic value and visibility	1
1.5	Ambient Air Quality and Emission standards	1
1.6	Ambient and stack sampling and Analysis of Particulate and Gaseous Pollutants.	1
1.7	Air quality sensors	1
	MODULE II (7 Hours)	
2.1	Effects of meteorology on Air Pollution - Fundamentals, Atmospheric stability	1
2.2	Dry adiabatic lapse rate derivation	1
2.3	Inversion, Wind profiles and stack plume patterns	1
2.4	Inversion, Wind profiles and stack plume patterns	
2.5	Atmospheric Diffusion Theories– Dispersion models	1

2.6	Atmospheric Diffusion Theories– Dispersion models	1
2.7	Plume Rise-Numerical Problems.	1
MODULE III (8 Hours)		
3.1	Gas Particle Interaction – Working principle	1
3.2	Design and performance equations of Gravity Separators	1
3.3	Centrifugal separators. Theory and numerical problem	1
3.4	Centrifugal separators. Theory and numerical problem	1
3.5	Fabric filters	1
3.6	Particulate Scrubbers	1
3.7	Electrostatic Precipitators –Operational Considerations	1
3.8	Factors affecting Selection of Control Equipment	1
MODULE IV (7 Hours)		
4.1	Working principle, Design and performance equations of absorption, Adsorption	1
4.2	Condensation, Incineration	1
4.3	Bio scrubbers	1
4.4	Venturi scrubber	1
4.5	Bio filters – Process control and Monitoring – Operational Considerations	1
4.6	Factors affecting Selection of Control Equipment	1
4.7	CO2 capturing, Hydrocarbon removal.	1
MODULE V (7 Hours)		
5.1	Sources types and control of indoor air pollutants	1
5.2	Sick building syndrome, types	1

5.3	HVAC system.	1
5.4	IAQ issues and impacts on occupants	1
5.5	Developing an IAQ profile	1
5.6	Diagnose IAQ problem	1
5.7	Control-Quantification and Measurement	1

CO Assessment Sample Questions	
1	List the sources of air pollution. Classify the sources of air pollution based on pollutant generation (Primary & Secondary) and pollutant types (gaseous, particulate dust etc.) with suitable examples.
2	List and explain the NAAQ standards and its importance.
3	Derive the expression for environmental lapse rate and dry adiabatic lapse rate.
4	A multi-tray settling chamber handles 6 m3/s of air at 20 °C. There are 8 trays including the bottom surface spaced 0.25 m apart. The chamber is 4 m long and 1 m wide. For particles of density 2000 kg/m3 and sizes (a) 70 µm and (b) 25 µm, calculate residence time (t), the distance settled (h) and the efficiency of collection (η). Is the tray spacing sufficient to collect all the particles of each size? Assume laminar flow. Given, µg at 20 °C = 1.81×10-5 kg/m-s, kinematic viscosity =1.51×10-5 m2/s.
5	(a) Explain the influence of HVAC system in indoor air quality depletion. (b) Explain the sources and impact of radon and molds in indoor air quality depletion.

24CHE624	FIRE SAFETY ENGINEERING	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: Fire safety in chemical process plants requires a specialized focus due to unique challenges posed by handling and processing of hazardous materials. This course is intended to impart knowledge on physics and chemistry of fire, fire prevention techniques, fire detection and control in process industries. It also outlines the elements of emergency planning and preparedness for a fire incident.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Explain physics and chemistry of fire.
CO2	Suggest suitable techniques to prevent fire in chemical process industries
CO3	Explain the working principle of different types of fire detectors and alarm system and plan and distribute them in buildings of different occupancy.
CO4	Interpret the concept of fire extinguishment with different extinguishants.
CO5	Describe the elements of emergency planning and preparedness for a fire incident.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	3	2				2				2		2
CO 2	3	2				2				2		2
CO 3	3	2				2				2		2
CO 4	3	2				2				2		2
CO 5	3	2				2				2		2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	□	□	□	□
Understand	□	□	□	□
Apply	□	□	□	□
Analyse			□	
Evaluate			□	
Create			□	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	**40**

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Fundamentals of Fire Processes

Elements of fire- Classes of fire- NFPA diamond- Principles of fire spread- Measures of flammability: Flash point, Fire point, Autoignition temperature, LFL and UFL- Flammability limit dependence on temperature and pressure- Estimating flammability limits-Flammability diagram: Construction and application-Products of combustion: Flame, heat, smoke, fire gases- Development of fire- incipient, smoldering, flame and heat stages-Special kinds of combustion-Flash fire, Pool fire, Jet fire, Deep seated fire, Spoil over, Boil over, Slope over, Dust explosion, BLEVE,
UVCE.

MODULE II: Fire Prevention Techniques

Control of Ignition Sources: Electrical Area Classification -Personal ignition sources- Hot work- Static Electricity: Fundamentals, Electrostatic discharges, streaming current, controlling of static electricity: Methods to prevent electrostatic ignitions.

Controlling oxygen levels: Limiting oxygen concentration-Inerting-Vacuum and pressure purging-Advantages and Disadvantages of the Various Pressure and Vacuum purging Procedures.

MODULE III: Fire detection and fire alarm systems

Fire detection- Need and importance of automatic fire detection system, principle of detection, classification of detectors; Heat detectors -Smoke detectors- Flame detectors -Flammable gas detection.

Fire alarm system- classification of alarm system-Automatic alarm system-various components and modules; Addressable and non-addressable system.

MODULE IV: Principles of Fire Extinguishments

Basic concept of firefighting with water, carbon dioxide, powders, foams, halons; Need for halon replacement and halon substitutes.

Description, working principle, method of operation of different types of portable fire extinguishers-water type, foam type, dry powder type, CO2 type. Automatic water sprinkler system-Total flooding system.

MODULE V: Fire Emergency Response

Emergency management: Laws regulations and industry codes of practice-Fire risk assessment- Resources-Planning-Training drills and exercises.

Human factors in emergencies: Human behaviour and fire-Basics of egress design- Techniques of crowd management-Strategies for occupant evacuation during emergencies.

Text books

1. Daniel A Crowl & Joseph F Louvar, Chemical Process Safety, Second Edition, Prentice-Hall.
2. Barendra Mohan Sen. Fire protection and prevention the essential handbook, UBS publishers and Dist., New Delhi. (2013).

Reference books

1. Daniel E. Della-Giustina, Fire Safety Management Handbook, Third Edition, CRC press.
2. S.K Biswas & Umesh Matur, Fundamentals of Process Safety Engineering, CRC Press.
3. Rasbash D., Ramachandran G., Kandola B., Watts, J., Law M., Evaluation of Fire Safety, John Wiley & Sons Ltd., England, (2004).
4. NFPA Fire protection handbook
5. SFPE Handbook of Fire Protection Engineering, Fifth Edition, Springer.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1 (8 hours)	
1.1	Elements of fire- Classes of fire- NFPA diamond- Principles of fire spread.	1
1.2	Measures of flammability: Flash point, Fire point, Autoignition temperature.	1
1.3	LFL and UFL. -Flammability limit dependence on temperature and pressure- Estimating flammability limits.	1
1.4	Flammability diagram: Construction and application.	1
1.5	Flammability diagram: Construction and application.	1
1.6	Products of combustion: Flame, heat, smoke, fire gases,Development of fire- incipient, smoldering, flame and heat stages.	1
1.7	Special kinds of combustion-Flash fire, Pool fire, Jet fire.	1
1.8	Deep seated fire, Spoil over, Boil over, Slope over, Dust explosion, BLEVE, UVCE.	1
	MODULE II (8 hours)	
2.1	Control of Ignition Sources: Electrical Area Classification - Personal ignition sources-Hot work.	1
2.2	Static Electricity: Fundamentals,Electrostatic discharges,streaming current.	1
2.3	Controlling of static electricity: Methods to prevent electrostatic ignitions.	1

2.4	Controlling of static electricity: Methods to prevent electrostatic ignitions.	1
2.5	Controlling oxygen levels: Limiting oxygen concentration- Inerting.	1
2.6	Vacuum purging.	1
2.7	Pressure purging.	1
2.8	Advantages and Disadvantages of the Various Pressure and Vacuum purging Procedures.	1
MODULE III (7 hours)		
3.1	Fire detection- Need and importance of automatic fire detection system, principle of detection.	1
3.2	classification of detectors; Heat detectors -Smoke detectors- Flame detectors -Flammable gas detection.	1
3.3	Smoke detectors.	1
3.4	Flame detectors -Flammable gas detection.	1
3.5	Fire alarm system- classification of alarm system.	1
3.6	Automatic alarm system-various components and modules.	1
3.7	Addressable and non-addressable system.	1
MODULE IV (7 hours)		
4.1	Basic concept of firefighting with water, carbon dioxide, powders, foams, halons; Need for halon replacement and halon substitutes.	1
4.2	Basic concept of firefighting with water, carbon dioxide, powders, foams, halons; Need for halon replacement and halon substitutes.	1
4.3	Description, working principle, method of operation of different types of portable fire extinguishers-water type, foam type.	1

4.4	Description, working principle, method of operation of different types of portable fire extinguishers- dry powder type, CO2 type.	1
4.5	Automatic water sprinkler system-Dry pipe and wet pipe.	1
4.6	Automatic water sprinkler system-Preaction and deluge systems.	1
4.7	Total flooding system.	1
MODULE V (5 hours)		
5.1	Emergency management: Laws regulations and industry codes of practice.	1
5.2	Fire risk assessment- Resources-Planning-Training drills and exercises.	1
5.3	Human factors in emergencies: Human behaviour and fire.	1
5.4	Basics of egress design.	1
5.5	Techniques of crowd management-Strategies for occupant evacuation during emergencies.	1

CO Assessment Sample Questions	
1	A vessel has been constructed for storage of liquefied butane under pressure at ambient temperature. It is to be commissioned by filling liquefied butane from another tank. The vessel has been checked for mechanical integrity and contains air at atmospheric pressure. The LFL for butane in air is equal to that in oxygen (1.8% by volume). The UFLs are 8.4 vol% in air and 49 vol% in oxygen. The minimum oxygen percentage below which no mixture is flammable is 12 Volume %. Draw the flammability diagram of butane. Based on the diagram suggest the methods to avoid fire and explosion during filling operation.
2	Ethylene oxide is a flammable liquid having a normal boiling temperature below room temperature. Describe a system and a procedure for transferring ethylene oxide from a tank car through a pumping system to a storage tank.

3	Distinguish between addressable and non-addressable alarm systems.
4	Prepare a table of suitability of various types of fire extinguishers for different classes of fire.
5	Discuss the factors that govern the effectiveness of emergency response in case of a fire incident.

24CHE634	PROCESS MODELLING AND SIMULATION	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: Modelling and simulation are important tools for engineers and scientists to have better understanding about the behavior of chemical processes and plants. They are very useful to design, scale up and optimize pieces of equipment and chemical plants for process control, troubleshooting, operational fault detection, training of operators and engineers, costing and operational planning etc. The course deals with the fundamentals of modelling and simulation, models of reactors, heat transfer equipments and separation processes.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Comprehend the fundamental laws and thermodynamic principles required for formulating a mathematical model.
CO2	Identify steps in building mathematical models for chemical processes
CO3	Develop models for complex chemical processes using shell balance approach.
CO4	Solve built-in models for chemical processes.
CO5	Develop models for complex chemical processes using UNISIM.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	2	3							2
CO2	3	3	3	2	3							2
CO3	3	3	3	2	3							2
CO4	3	3	3	2	3	3						2
CO5	3	3	3	2	3							2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test2	Other tools	
Remember	□	□	□	□
Understand	□	□	□	□
Apply	□	□	□	□
Analyse			□	
Evaluate			□	
Create			□	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 HOURS

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Fundamentals of Modeling

Introduction to process modeling, needs of model and their classification, Model building, Precautions in model building, Principles of model formulation, Fundamental laws, Review of shell balance approach, Models based on thermodynamic principles, Concept of the degree of freedom analysis, Concept of equilibrium and kinetics

MODULE II: Models of Reactors
Batch reactor model, Semi Batch reactor, Interacting and Non-Interacting Tanks, two heated tanks, Gas phase pressurized CSTR, non-isothermal CSTR: Perfectly mixed cooling jacket, Plug flow cooling jacket, Lumped Jacket Model, Lumped metal model, Reactor model with mass transfer, Bioreactor models. Fluidized bed reactor model, Trickle Bed Reactor Model.

MODULE III: Models of Heat Transfer Equipment
One and two-dimensional heat conduction, Numerical solution of one dimensional transient heat conduction in a rectangular slab, cylinder, and sphere using the finite difference method.
MODULE IV: Models of Separation Processes
Development of detailed Single-Component Vaporizer, Development of detailed mathematical models of multicomponent flash drum, Binary Batch & Continuous Distillation Column, Multicomponent non-ideal distillation column, Batch distillation with holdup, Activity coefficient model (Wilson, NRTL, UNIQUAC,UNIFAC), Equation of State Models (RK, SRK, PR).
MODULE V: Simulation
Introduction to process simulation, Tools of simulation- Features, Advantages and limitations; Approaches of simulation: Modular approach and Equation solving approach, Flowsheeting, Introduction to dynamic simulation and process optimization.
Text books 1. Franks R.G.E., Mathematical Modeling in Chemical Engineering, John Wiley 2. Luyben W.L., Process Modeling, Simulation and Control for Chemical Engineers, McGraw Hill International Edition 3. Amiya K.Jana, Computer Process Modelling and Computer Simulation, Prentice Hall of India.
Reference books 1. Biquette W.B., Process Dynamics - Modeling Analysis and Simulation, Prentice Hall of India. 2. John Ingham et.al., Chemical Engineering Dynamics - Modeling with PC Simulation, VCH Publishers.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours

MODULE 1 (8 hours)		
1.1	Introduction to process modeling, needs of model and their classification	1
1.2	Model building, Precautions in model building	1
1.3	Principles of model formulation	1
1.4	Fundamental laws, Review of shell balance approach	1
1.5	Fundamental laws, Review of shell balance approach	1
1.6	Models based on thermodynamic principles	1
1.7	Concept of the degree of freedom analysis, Concept of equilibrium and kinetics	1
1.8	Concept of the degree of freedom analysis, Concept of equilibrium and kinetics	1
MODULE II (8 hours)		
2.1	Batch reactor model, Semi Batch reactor	1
2.2	Batch reactor model, Semi Batch reactor	1
2.3	Interacting and Non nteracting tanks, two heated tanks	1
2.4	Gas phase pressurized CSTR, non-isothermal CSTR: Perfectly mixed cooling jacket,	1
2.5	Gas phase pressurized CSTR, non-isothermal CSTR: Perfectly mixed cooling jacket	1
2.6	Plug flow cooling jacket, Lumped Jacket Model	1
2.7	Lumped metal model, Reactor model with mass transfer, Bioreactor models	1
2.8	Fluidized bed reactor model, Trickle Bed Reactor Model.	1
MODULE III (6 hours)		

3.1	One- and Two-dimensional heat conduction	1
3.2	Numerical solution of one-dimensional transient heat conduction in a rectangular slab, cylinder, and sphere using the finite difference method.	1
3.3	Numerical solution of one-dimensional transient heat conduction in a rectangular slab, cylinder, and sphere using the finite difference method	1
3.4	Numerical solution of one-dimensional transient heat conduction in a rectangular slab, cylinder, and sphere using the finite difference method	1
3.5	Numerical solution of one-dimensional transient heat conduction in a rectangular slab, cylinder, and sphere using the finite difference method.	1
3.6	Numerical solution of one-dimensional transient heat conduction in a rectangular slab, cylinder, and sphere using the finite difference method.	1

MODULE IV (5 hours)		
4.1	Development of detailed Single-ComponentVaporizer, Development of detailed mathematical models of multicomponent flash drum	1
4.2	Binary Batch & Continuous Distillation Column, Multicomponent non-ideal distillation column	1
4.3	Batch distillation with holdup, Activity coefficient model (Wilson, NRTL, UNIQUAC, UNIFAC), Equation of State Models (RK, SRK, PR).	1
4.4	Batch distillation with holdup, Activity coefficient model(Wilson, NRTL, UNIQUAC, UNIFAC), Equation of State Models (RK, SRK, PR).	1
4.5	Batch distillation with holdup, Activity coefficient model (Wilson, NRTL, UNIQUAC, UNIFAC), Equation of State Models (RK, SRK, PR).	1
MODULE V (9 hours)		
5.1	Introduction to process simulation, Tools of simulation-Features, Advantages and limitations	1
5.2	Introduction to process simulation, Tools of simulation-Features, Advantages and limitations	1
5.3	Approaches of simulation: Modular approach and Equation solving approach	1

5.4	Approaches of simulation: Modular approach and Equation solving approach	1
5.5	Approaches of simulation: Modular approach and Equation solving approach	1
5.6	Flow sheeting, Introduction to dynamic simulation and process optimization.	1
5.7	Flow sheeting, Introduction to dynamic simulation and process optimization	1
5.8	Introduction to dynamic simulation and process optimization.	1
5.9	Introduction to dynamic simulation and process optimization	1

CO Assessment Sample Questions	
1	Explain principles of formulation.
2	Explain Transport equations and equations of continuity.
3	Develop the model of one-dimensional transient heat conduction in a rectangular slab.
4	Develop the model of jacketed tubular reactor.
5	Develop the model of gravity flow tank using UNISIM.
6	Explain the need for simulation softwares.

24CHE644	OIL & NATURAL GAS ENGINEERING	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: This course introduces the fundamentals of oil and natural gas engineering including the origin and formation of Petroleum and petroleum geology. Students will get understanding about the various exploration techniques and well logging methods. The course provides an insight to oil well drilling and its completion.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Explain the fundamentals of petroleum geology and exploration.
CO2	Summarize the basics of logging, drill and production techniques practiced in the oil wells.
CO3	Apply the fundamental concepts in the oil and gas reservoir engineering.
CO4	Outline the geology, origin, reservoir characteristicsand production technology of unconventional oil.
CO5	Discuss the geology, origin, reservoir characteristics and production technology of unconventional gases.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3					2	2					2
CO2	3					2	2					2
CO3	3					2	2					2
CO4	3					2	2					2
CO5	3					2	2					2

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	☐	☐	☐	☐
Understand	☐	☐	☐	☐
Apply	☐	☐	☐	☐
Analyse			☐	
Evaluate			☐	
Create			☐	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	**5**	**15**	**10**	**10**	**40**

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 Hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Fundamentals of petroleum geology and exploration

Introduction, origin, formation, geological occurrence and characteristics of oil and natural gas. Source Rocks, Reservoir Rocks, and Cap rocks: Definition, Characteristics, Classification and nomenclature, Concept of Shale oil, Reservoir Properties, Hydrocarbon migration, Petroleum Exploration.

MODULE II: Introduction to well drilling and production

Well logging: Direct Methods: Mud logging- coring – conventional and sidewall coring – Core analysis. Concepts of well logging: Logging Terminology-Borehole environment- Major components of well logging unit and logging setup-Classification of well logging methods. Well Drilling: cable tool drilling, rotary drilling, types of drilling units, and types of production units. Well completion, Production methods.

MODULE III: Fundamentals of Oil and Gas Reservoir Engineering

Some basic concepts in reservoir engineering: Calculation of hydrocarbon volumes- Fluid pressure regimes- Oil recovery and recovery factor-Volumetric gas reservoir engineering- Gas material balance and recovery factor-Hydrocarbon phase behaviour. Reservoir deliverability: Flow regimes, IPR for various types of wells, well bore performance, well deliverability, well decline analysis.

MODULE IV: Non-Conventional Oil

Shale oil: Introduction, geology, origin, types of oil shales, and occurrence worldwide, Kerogen and its composition, production technologies. Tar Sand: Introduction, geology, origin and occurrence worldwide, composition, resources, production technologies. Heavy oil: Introduction, geology, origin and occurrence worldwide, composition and production technologies.

MODULE V: Non-conventional gas

Introduction, present status, formation and properties of coal bed methane, natural gas hydrate, tight gas sands, shale gas. Shale Gas: Exploration, Production-Drilling and completion. Natural Gas Hydrate: Concepts and Structures, Evaluation and Prediction, Production Techniques.

Text books

1. Elements of Petroleum Geology, Richard, C. Selley, Elsevier, 1997.
2. Dake L. P., “Fundamentals of Reservoir Engineering”, Elsevier Science B. V, 1978.
3. Manjooran S. K. B., “Modern Petroleum Chemistry”, Kannatheri Publication, 2004.
4. Beggs D. H., “Gas Production Operations”, OGCI Publications, 1984.

Reference books

1. Petroleum Production Engineering: A Computer Assisted Approach, BoyunGuo,William C. Lyons, Ali Ghalambor, Elesevier Science & Technology Books, 2007.
2. James G. Speight,"Shale Oil Production Processes", Gulf Professional Publishing,2012
3. Carrol John, "Natural Gas Hydrates: A guide for engineers", Gulf Professional Publishing, 2003
4. Rafiqul Islam, M., "Unconventional Gas Reservoirs: Evaluation, Appraisal, and Development", Gulf Professional Publishing, 2014

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1 (5 hours)	
1.1	Introduction, origin, formation, geological occurrence and characteristics of oil and natural gas.	1
1.2	Source Rocks, Reservoir Rocks, and Cap rocks: Definition, Characteristics.	1
1.3	Source Rocks, Reservoir Rocks, and Cap rocks: Classification and nomenclature.	1
1.4	Concept of Shale oil, Reservoir Properties.	1
1.5	Hydrocarbon migration, Petroleum Exploration.	1
	MODULE II (6 hours)	
2.1	Well logging: Direct Methods: Mud logging- coring – conventional and sidewall coring – Core analysis.	1
2.2	Concepts of well logging: Logging Terminology- Borehole environment-	1
2.3	Major components of well logging unit and logging setup- Classification of well logging methods.	1
2.4	Well Drilling: cable tool drilling, rotary drilling, types of drilling units, and types of production units.	
2.5	Well Drilling: cable tool drilling, rotary drilling, types of drilling	1

	units, and types of production units.	
2.6	Well completion, Production methods	1
	MODULE III (7 hours)	
3.1	Some basic concepts in reservoir engineering: Calculation of hydrocarbon volumes-	1
3.2	Some basic concepts in reservoir engineering: Fluid pressure regimes	1
3.3	Oil recovery and recovery factor	1
3.4	Volumetric gas reservoir engineering- Gas material balance and recovery factor-.	1
3.5	Hydrocarbon phase behaviour. Reservoir deliverability: Flow regimes	1
3.6	IPR for various types of wells, well bore performance	1
3.7	Well deliverability, well decline analysis	1
	MODULE IV (9 hours)	
4.1	Shale oil: Introduction, geology, origin, types of oil shales, and occurrence worldwide,	1
4.2	Shale oil: Introduction, geology, origin, types of oil shales, and occurrence worldwide,	1
4.3	Kerogen and its composition, production technologies.	1
4.4	Tar Sand: Introduction, geology	1
4.5	Tar Sand: origin and occurrence worldwide	1
4.6	Tar Sand: composition, resources, production technologies.	1
4.7	Heavy oil: Introduction, geology	1
4.8	Heavy oil: origin and occurrence worldwide	1

4.9	Heavy oil: composition and production technologies.	1
MODULE V (9 hours)		
5.1	Introduction, present status, formation and properties of coal bed methane	1
5.2	Introduction, present status, formation and properties natural gas hydrate.	1
5.3	Introduction, present status, formation and properties tight gas sands.	1
5.4	Introduction, present status, formation and properties shale gas.	1
5.5	Shale Gas: Exploration, Production-Drilling and completion.	1
5.6	Shale Gas: Exploration, Production-Drilling and completion.	1
5.7	Natural Gas Hydrate: Concepts and Structures	1
5.8	Natural Gas Hydrate: Evaluation and Prediction	1
5.9	Natural Gas Hydrate: Production Techniques	1

CO Assessment Sample Questions	
1	Explain magnetic and seismic method for the exploration of petroleum.
2	Explain main types of logs used in well logging.
3	Suppose that a vertical well produces 0.71 specific gravity gas through a 2.875 –in tubing set to the top of a gas reservoir at a depth of 10,000 ft. At tubing head, the pressure is 800 psia and the temperature is 150 °F, whereas the bottom-hole temperature is 200 °F. The relative roughness of tubing is about 0.0006. Calculate the expected gas production rate of the well using the following data for IPR: Reservoir pressure = 2,000 psia, IPR model parameter, C = 0.1 Mscf/d-psi^{2n} ,IPR model parameter, n = 0.8

4	Explain the formation of tar sand and outline the composition of oil shales.
5	Differentiate depressurization and thermal stimulation for the production of gas hydrates.

24CHE654	CORROSION ENGINEERING	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: This course is intended to impart knowledge on the importance of corrosion and its prevention in process industries. Different forms of corrosion and corrosion testing methods are discussed. This course also gives an overview about its control techniques.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Summarize the principles of corrosion considering electrochemical, environmental, metallurgical and other aspects.
CO2	Identify and explain the different types of corrosion.
CO3	Explain various corrosion testing and control techniques.
CO4	Select the appropriate corrosion control technique for different engineering materials and industries.
CO5	Identify corrosion-related problems and propose viable solutions.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3					3					2
CO2	3	3				2	2					2
CO3	3	3				1	1					2
CO4	3	3				1	1					2
CO5	3	3				2	3					2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	□	□	□	□
Understand	□	□	□	□
Apply	□	□	□	□
Analyse			□	
Evaluate			□	
Create			□	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	**Attendance**	Theory [L- T]			**Total Marks**
		Assignment	**Test-1**	**Test-2**	
3-0-0-0	**5**	**15**	**10**	**10**	**40**

Total Mark distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Definition and importance of corrosion

Definition and importance of corrosion, Principles of corrosion phenomenon, Corrosion rate expressions, Electrochemical aspects, Environmental effects, Metallurgical and other aspects.

MODULE II: Different forms of corrosion

Different forms of corrosion: Galvanic or two metal corrosion, Crevice corrosion, Pitting, Intergranular corrosion, Selective leaching, Erosion corrosion, Stress corrosion, Hydrogen damage.

MODULE III: Corrosion testing and monitoring

Corrosion testing and monitoring: Non-electrochemical and electrochemical methods-potentiostat, Tafel extrapolation, linear polarization, galvanostat, impedance spectroscopy, thermogravimetric technique, salt spray test, weight change measurements.

MODULE IV: Corrosion prevention

Corrosion prevention: Design and coatings, inhibitors and surface engineering, cathodic protection and anodic protection

MODULE V: Corrosion and its control in different engineering materials and industries

Corrosion and its control in different engineering materials: concrete structures, duplex, super duplex stainless steels, ceramics, composites and polymers. Corrosion and its control in industries: Power, Process, Petrochemical, ship building, marine and fertilizer industries. Corrosion auditing in industries, Corrosion map of India.

Text books

1. Fontana M. G., Corrosion Engineering, Tata McGraw Hill, 3rd Edition, 2005.
2. Jones D. A, Principles and Prevention of Corrosion, Prentice-Hall, Inc., 2nd Edition, 1996.

Reference books

1. Scully J. C, The Fundamentals of Corrosion, 2nd Ed., Pergamon Press.
2. Stansbury E. E. and Buchanan, R. A, Fundamentals of Electrochemical Corrosion, ASM International.
3. Uhlig H. H. and Revie R. W, Corrosion and Corrosion Control, 3rd Ed., John Wiley & Sons.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE 1 (8 hours)		
1.1	Definition and importance of corrosion	1
1.2	Principles of corrosion phenomenon	1
1.3	Principles of corrosion phenomenon	1
1.4	Corrosion rate expressions	1
1.5	Electrochemical aspects	1

1.6	Electrochemical aspects	1
1.7	Environmental effects	1

1.8	Metallurgical and other aspects	1
MODULE II (7 hours)		
2.1	Different forms of corrosion	1
2.2	Galvanic or two metal corrosion	1
2.3	Crevice corrosion	1
2.4	Pitting, Intergranular corrosion.	1
2.5	Selective leaching,	1
2.6	Erosion corrosion	1
2.7	Stress corrosion, Hydrogen damage	1
MODULE III (7 hours)		
3.1	Corrosion testing and monitoring:	1
3.2	Non-electrochemical and electrochemical methods: potentiostat,	1
3.3	Tafel extrapolation	1
3.4	linear polarization, galvanostat	1
3.5	impedance spectroscopy,	1
3.6	thermogravimetric technique,	1
3.7	salt spray test, weight change measurements	1
MODULE IV (5 hours)		
4.1	Corrosion prevention:	1
4.2	Design and coatings	1

4.3	Inhibitors and surface engineering	1
4.4	cathodic protection	1
4.5	anodic protection	1

MODULE V (9 hours)		
5.1	Corrosion and its control in different engineering materials:	1
5.2	concrete structures, duplex, super duplex stainless steels	1
5.3	ceramics, composites and polymers.	1
5.4	Corrosion and its control in Power industries	1
5.5	Corrosion and its control in Process Petrochemical industries	1
5.6	Corrosion and its control in ship building, marine industries.	1
5.7	Corrosion and its control in Fertilizer industries.	1
5.8	Corrosion auditing in industries.	1
5.9	Corrosion map of India.	1

CO Assessment Sample Questions	
1	Explain the electrochemical aspects of corrosion.
2	Explain galvanic corrosion with a neat sketch.
3	Explain galvanostatic method of corrosion testing.
4	Explain various corrosion control techniques.
5	Discuss the need for conducting corrosion auditing in industries.

24CHE664	FUELS AND COMBUSTION	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: This course provides a comprehensive understanding of fuels and combustion. Key topics in this course includes solid, liquid and gaseous fuels, their origin, classification, preparation procedure and characterization in terms of physico- chemical properties, combustion and the environmental Impact of combustion processes.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Explain the importance of biofuels and hydrogen as a fuel, the chemical composition, properties, and types of fuels.
CO2	Explain the various types of solid and liquid fuels, their preparation, analysis, and properties, as well as the different methods of refining, testing, and handling liquid fuels.
CO3	Recognize the specific applications of different gaseous fuels, in various engine systems including spark ignition engines, compression engines, jet engines, and rockets.
CO4	Analyze and calculate theoretical air requirements, flue gas composition, and combustion kinetics for hydrogen-oxygen and hydrocarbon-oxygen reactions.
CO5	Assess environmentally responsible combustion practices, including emission control technologies and life cycle analysis for sustainable energy applications.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3				2						2
CO2	3	3				2						2
CO3	3	3				2						2
CO4	3	3				2						2
CO5	3	3				2	3					2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	□	□	□	□
Understand	□	□	□	□
Apply	□	□	□	□
Analyse			□	
Evaluate			□	
Create			□	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3hr

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Introduction to Fuels and Combustion

Chemical composition and properties of fuels. Definition of fuels and their role as energy sources. Importance of fuels in meeting global energy demands. Fuels - Types and Characteristics of Fuels - Introduction to Green Fuels, Definition and characteristics of green fuels. Importance of transitioning to environmentally friendly fuel alternatives. Types of Green Fuels, Biofuels: Production, sources, and advantages- Introduction to Hydrogen as a Fuel: Definition and properties of hydrogen. Comparison of hydrogen with conventional fuels. Importance of hydrogen as a clean and sustainable energy carrier.

MODULE II: Solid fuels and liquid fuels

Solid fuels – Classification, preparation, cleaning, analysis, ranking and properties – action of heat, oxidation, hydrogenation, carbonization, liquefaction and gasification. Liquid fuels – Petroleum – origin, production, composition, classification, petroleum processing, properties, testing – flow test, smoke points, storage and handling. Secondary liquid fuels – Gasoline, diesel, kerosene and lubricating oils. Modified and synthetic liquid fuels. ASTM methods of testing the fuels. Properties of Liquid Fuels -Calorific Value, Specific Gravity, Flash & Fire Point, Octane Number and Cetane Number.

MODULE III: Gaseous fuels

Gaseous fuels – Types, natural gas, methane from coal mine, water gas, carrier gas, producer gas, flue gas, blast furnace gas, biomass gas, refinery gas, LPG – manufacture, cleaning, purification and analysis. Fuels for spark ignition engines, knocking and octane number, anti-knock additives, fuels for compression, engines, octane number, fuels for jet engines and rockets. Flue gas analysis by chromatography and sensor techniques.

MODULE IV: Combustion

Combustion: Stoichiometry, thermodynamics. Nature and types of combustion processes – Mechanism – ignition temperature, explosion range, flash and fire points, calorific value, calorific intensity, theoretical flame temperature. Combustion calculations, theatrical air requirements, flue gas analysis, combustion kinetics – hydrogen – oxygen reaction and hydrocarbon – oxygen reactions.

MODULE V: Combustion and Environmental Impact

Rocket propellants and Explosives – classification, brief methods of preparation, characteristics; storage and handling emissions: Effects of pollutants, Quantification of emissions, Emission from premixed combustion, Emissions from non-premixed combustion. Control technologies for reducing emissions-Combustion and climate change mitigation-Life cycle analysis and sustainability of combustion processes.

Text books

1. Fuels and Combustion, Samir Sarkar, Orient Longman Pvt. Ltd, 3rd edition, 2009.
2. "Fuels and Combustion" by S.P. Sharma and Chander Mohan.

Reference books.

1. An introduction to combustion: Concept and applications – Stephen R Turns, Tata Mc. Graw Hill, 3rd edition, 2012.
2. Fundamentals of Combustion, D P Mishra, 1st edition, University Press, 2010
3. Engineering Chemistry – R. Mukhopadhyay and Sriparna Datta, Newage International Pvt. Ltd, 2007.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1 (7 hours)	
1.1	Chemical composition and properties of fuels. Definition of fuels and their role as energy sources.	1
1.2	Importance of fuels in meeting global energy demands. Fuels - Types and Characteristics of Fuels.	1
1.3	Introduction to Green Fuels, Definition and characteristics of green fuels.	1
1.4	Importance of transitioning to environmentally friendly fuel alternatives. Types of Green Fuels.	1
1.5	Biofuels: Production, sources, and advantages.	1
1.6	Introduction to Hydrogen as a Fuel: Definition and properties of hydrogen.	1
1.7	Comparison of hydrogen with conventional fuels. Importance of hydrogen as a clean and sustainable energy carrier.	1
	MODULE II (7 hours)	
2.1	Solid fuels – Classification, preparation, cleaning, analysis, ranking and properties	1
2.2	Action of heat, oxidation, hydrogenation, carbonization, liquefaction and gasification	1
2.3	Liquid fuels – Petroleum – origin, production, composition,	1

	classification	
2.4	petroleum processing, properties, testing – flow test, smoke points, storage and handling	1
2.5	Secondary liquid fuels – Gasoline, diesel, kerosene and lubricating oils	1
2.6	Liquid fuels – refining, cracking, fractional distillation, polymerization. Modified and synthetic liquid fuels. ASTM methods of testing the fuels	1
2.7	Properties of Liquid Fuels -Calorific Value, Specific Gravity, Flash & Fire Point, Octane Number, Cetane Number etc	1
	MODULE III (8 hours)	
3.1	Gaseous fuels – Types, natural gas, methane from coal mine, water gas, carrier gas, producer gas.	1
3.2	Flue gas, blast furnace gas, biomass gas, refinery gas.	1
3.3	LPG – manufacture, cleaning, purification and analysis	1

3.4	Fuels for spark ignition engines, knocking and octane number, anti knock additives.	1
3.5	Fuels for spark ignition engines, knocking and octane number, anti knock additives.	1
3.6	Fuels for compression, engines, octane number.	1
3.7	Fuels for jet engines and rockets, Fuels for spark ignition engines	1
3.8	Knocking and octane number, anti knock additives. Flue gas analysis by chromatography and sensor techniques.	1
	MODULE IV (6 hours)	
4.1	Combustion: Stoichiometry, thermodynamics Nature and types of combustion processes	1
4.2	Mechanism – ignition temperature, explosion range, flash and fire points.	1

4.3	Calorific value, calorific intensity, theoretical flame temperature	1
4.4	Combustion calculations, theatrical air requirements, flue gas analysis.	1
4.5	Combustion kinetics – hydrogen – oxygen reaction and hydrocarbon – oxygen reactions.	1
4.6	Combustion kinetics – hydrogen – oxygen reaction and hydrocarbon – oxygen reactions.	1
MODULE V (7 hours)		
5.1	Rocket propellants and Explosives – classification, brief methods of preparation, characteristics; storage and handling. missions:	1
	Rocket propellants and Explosives – classification, brief methods of preparation, characteristics; storage and handling. missions	1
5.2	Effects of pollutants, Quantification of emissions	1
5.3	Emissions from non-premixed combustion. Air pollution from combustion processes -Greenhouse gas emissions and global warming potential	1
5.4	Emissions from non-premixed combustion. Air pollution from combustion processes -Greenhouse gas emissions and global warming potential	1
5.5	Control technologies for reducing emissions- Combustion and climate change mitigation	1
5.6	Control technologies for reducing emissions- Combustion and climate change mitigation	1

5.7	Life cycle analysis and sustainability of combustion processes	1

CO Assessment Sample Questions	
1	Explain the role of chemical composition and properties of different fuels in its performance as energy source.

2	Describe the significance of ASTM methods of testing liquid fuels and how they contribute to ensuring fuel quality and safety.
3	Explain the significance of octane number in fuels for spark ignition engines and cetane number in fuels for compression engines. How do these ratings influence engine performance and efficiency?
4	Describe the concept of stoichiometry in combustion processes and how it relates to the calculation of theoretical air requirements.
5	Discuss how the life cycle analysis can be applied to evaluate the environmental impact of a combustion system. Provide specific examples of emission control technologies utilized to achieve environmentally responsible combustion practices for sustainable energy applications.

24CHE674	NUCLEAR ENGINEERING	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: The course focuses on the fundamentals of nuclear engineering. The content includes elementary nuclear physics, nuclear reactor, nuclear fuels, boiling water reactor, structural materials, reactor heat removal, safety and disposal methods for nuclear wastes. The course helps the students to understand the theories and principles of nuclear power generation, heat removal techniques and safe disposal methods.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Explain the engineering design of nuclear power plants using the basic principles of reactor physics, thermodynamics, fluid flow and heat transfer.
CO2	Explain the nuclear reactor principles, nuclear safety, and reactor dynamic behaviour.
CO3	Describe boiling water reactor, design, components and materials.
CO4	Explain heat transfer and heat removal systems.
CO5	Discuss the methods for nuclear waste disposal.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3										
CO2	3	2	2			2						
CO3	3	2	2									
CO4	3	2	3			2	3					
CO5	3	2	3			3	3					

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	□	□	□	□
Understand	□	□	□	□
Apply	□	□	□	□
Analyse			□	
Evaluate			□	
Create			□	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	**Attendance**	**Theory [L- T]**			**Total Marks**
		Assignment	**Test-1**	**Test-2**	
3-0-0-0	**5**	**15**	**10**	**10**	**40**

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Review of elementary Nuclear Physics

Review of Elementary nuclear physics: Atomic structure – nuclear energy and nuclear forces – Nuclear fission. Nuclear reactions and radiations – Principles of radioactive decay interactions of a ray with matter, types of radiation, radiation detection and measurement, nuclear models, Neutron cross sections and reactions – Chain reactions.
MODULE II: Principles & working of nuclear reactor
Basic principles of controlled fusion. Nuclear reactor principles – Reactor classification – Critical size. Basic diffusion theory - Slowing down of neutrons – Neutrons – Neutron flux and power – Four factor formula – Criticality condition –Basic features of reactor control.

MODULE III: Boiling water reactor
Boiling water reactor. Description of reactor system, construction, main components, working of reactor, Control and safety features, Materials of reactor construction –Fuel, moderator, coolant.
MODULE IV: Structural materials, nuclear fuels, Reactor heat transfer systems.
Structural materials – Cladding –Radiation damage, nuclear fuels: Metallurgy of Uranium – General principles of solvent extraction – Reprocessing of irradiated fuel – Separation process fuel enrichment. Reactor heat removal / equations of heat transfer as applied to reactor cooling– Reactor heat transfer systems – Heat removed in fast reactors.
MODULE V: Safety and disposal
Radiation safety: Reactor shielding – Radiation dozes – Standards of radiation protection. Safety and disposal: Nuclear plant safety-safety systems-changes and consequences of accident-criteria for safety-nuclear waste types of waste and its disposal-radiation hazards and their prevention-weapons proliferation.
Text books 1. S. Glasstone and A. Sesonske, Nuclear Reactor Engineering, D. Van Nostrand Company, INC. 1967. 2. 2. S Glasstone, Source book on atomic energy, Krieger Pub Co., 1979.
Reference books 1. Vaidyanathan.G., Nuclear Reactor Engineering (Principles and Concepts), S.Chand & Company, New Delhi, 2013. 2. Jacques Libmann, Elements of Nuclear Safety, Les Editions de Physique 1996.
COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE 1 (6 hours)		
1.1	Review of Elementary nuclear physics: Atomic structure – nuclear energy and nuclear forces.	1
1.2	Nuclear fission.	1
1.3	Nuclear reactions and radiations – Principles of radioactive decay interactions of a ray with matter.	1
1.4	Types of radiation, radiation detection and measurement.	1
1.5	Nuclear models, Neutron cross sections and reactions.	1
1.6	Chain reactions.	1

MODULE II (7 hours)		
2.1	Basic principles of controlled fusion.	1
2.2	Nuclear reactor principles.	1
2.3	Reactor classification, Critical size.	1
2.4	Basic diffusion theory, Slowing down of neutrons.	1
2.5	Neutrons – Neutron flux and power.	1
2.6	Four factor formula – Criticality condition.	1
2.7	Basic features of reactor control.	1
MODULE III (6 hours)		
3.1	Boiling water reactor, Description of reactor system.	1
3.2	Construction.	1
3.3	Main components.	1

3.4	Working of reactor.	1
3.5	Control and safety features.	1
3.6	Materials of reactor construction, – Fuel, moderator, coolant.	1
	MODULE IV (8 hours)	
4.1	Structural materials – Cladding –Radiation damage.	1
4.2	Nuclear fuels.	1
4.3	Metallurgy of Uranium, General principles of solvent extraction.	1
4.4	Reprocessing of irradiated fuel.	1
4.5	Separation process fuel enrichment	1
4.6	Reactor heat removal / equations of heat transfer as applied to reactor cooling.	1
4.7	Reactor heat transfer systems	1
4.8	Heat removed in fast reactors.	1
	MODULE V (8 hours)	
5.1	Radiation safety: Reactor shielding.	1
5.2	Radiation doses, Standards of radiation protection.	1
5.3	Safety and disposal: Nuclear plant safety.	1
5.4	Safety systems.	1
5.5	Changes and consequences of accident, criteria for safety.	1
5.6	Nuclear waste types of waste and its disposal.	1
5.7	Radiation hazards and their prevention.	1
5.8	Weapons proliferation.	1

CO Assessment Sample Questions	
1	a) Explain the radioactive decay law. b) Identify the radioactive reactions following, when a neutron is captured by U_{238} substance. c) Compare nuclear fission and nuclear fusion.
2	a) Explain the working of a reactor system in which nuclear fission is the working principle. b) Explain the basic features of nuclear reactor control.
3	Illustrate the working of a boiling water reactor with neat sketch.
4	Compare the heat removal system in a fast breeder reactor with that of a boiling water reactor. Derive heat conduction equation in the moderator.
5	Explain different types of nuclear wastes and list any five methods of its disposal.

24CHE684	POLYMER TECHNOLOGY	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: This Polymer Technology course encompasses a comprehensive study of topics including Molecular Weight of Polymers, Manufacture, Properties, and Applications of Bioplastics and Elastomers, Rheology and Testing of Polymers, Additives used, and the Processing of Plastics and Elastomers.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Understand the fundamentals and mechanisms of polymerisation, classification and methods of polymerisation.
CO2	Describe methods to find out average molecular weight of polymers and understand the factors affecting polymer properties.
CO3	Summarize the manufacture, properties and engineering applications of different polymeric materials.
CO4	Analyse the rheology and mechanical properties of polymers and to understand the functions of additives used in polymers.
CO5	Explain the processing methods of plastics and elastomers.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3											
CO2	3											
CO3	3											
CO4	3						2					
CO5	3					3						2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	☐	☐	☐	☐
Understand	☐	☐	☐	☐
Apply	☐	☐	☐	☐
Analyse			☐	
Evaluate			☐	
Create			☐	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	**40**

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3hr

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
Pattern 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I : Introduction to Polymers, Classification and kinetics

Introduction to polymers-monomer, functionality, classification of polymer based on source, structure, application, thermal behaviour, mode of polymerization. Kinetics of step growth polymerisation, addition polymerization and Ionic polymerisations - anionic and cationic polymerization. Copolymerisation-Different types of copolymers-Characteristics. Methods of polymerization – bulk, solution, suspension and emulsion polymerization.

MODULE II : Molecular weight of polymers

Molecular weight of polymers – weight average and number average molecular weight – sedimentation and viscosity average molecular weights. Experimental methods for molecular weight determination –

end group analysis, light scattering method viscometry(Ostwaldviscometer) intrinsic viscosity-sedimentation methods. Molecular weight distribution curve. Factors affecting polymer properties --crystallinity-orientation treatment-solubility of polymers-glass transition temperature – types of polymer degradation.

MODULE III : Manufacture,properties and applications Bioplastics, Elastomers

Manufacture (Detailed flow sheet not required), properties and applications of polymers- Thermoplastics-ABS – acrylics-cellulose acetate – fluoropolymers (PTFE)- nylons – polycarbonate-PVC-PE– PP – PS – polyurethanes. Thermosetting plastics – epoxy – phenol formaldehyde-urea formaldehyde – polyesters – silicones. Bioplastics – Poly lactic acid (PLA), Polyhydroxy Butyrate (PHB), Cellulose Acetate. Elastomers, Butyl rubber, Nitrile rubber.

MODULE IV : Rheology and Testing of polymers and additives used

Properties of polymers – rheology- viscous flow – apparent viscosity – rubber like elasticity – stress-strain behaviour of elastomers – viscoelasticity – measurement of rheological properties – melt flow index (MFI) – capillary rheometers. Estimation of mechanical properties like tensile strength, flexural strength, hardness and impact strength of polymers. Additives for polymer processing–- -effect of additives used – plasticizers – colourants – heat stabilizers - antioxidants.

MODULE V : Processing of plastics and elastomers

Plastic processing technology-injection moulding-compression moulding -calendaring – blow moulding – extrusion – thermoforming – wet, dry and melt spinning methods for fibres –vulcanization of rubber — general study of elastomer processing - brief description of compounding methods. Introduction to polymer nano composites-types and properties of nanofillers applications.

Text books

1. Billmeyer F.W., Text book of polymer science, John Wiley.
2. Gowariker V.R. Polymer Science, New Age.

Reference books

1. Premamoy Ghosh., Polymer Science and Technology, Tata Mc Graw Hill.
2. Rodrigues F., Principles of polymer systems, Tata Mc Graw Hill.
3. Shah V.H., Handbook of plastic testing technology, Wiley, 1998.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE 1 (8 hours)		
1.1	Monomer, functionality	1

1.2	Classification of polymer based on source, structure, application, thermal behaviour, mode of polymerization	1
1.3	Kinetics of step growth polymerization	1

1.4	Kinetics of addition polymerization- free radical polymerization	1
1.5	Ionic polymerisation-anionic and cationic polymerization	1
1.6	Different types of copolymers- Characteristic features, Copolymer equation.	1
1.7	Methods of polymerization – bulk, solution, suspension and emulsion polymerization	1
1.8	Methods of polymerization – bulk, solution, suspension and emulsion polymerization	1
MODULE II (7 hours)		
2.1	Weight average and number average molecular weight- Definition and types	1
2.2	Experimental methods of molecular weight determination- end group analysis	1
2.3	Determination of molecular weight by Light scattering method	1
2.4	Viscometry and Sedimentation methods,	1
2.5	Molecular weight distribution curve	1
2.6	Factors affecting polymer properties	1
2.7	Types of polymer degradation	1
MODULE III (7 hours)		
3.1	Thermoplastics-ABS – acrylics – cellulose acetate - fluoropolymers (PTFE) – nylons.	1
3.2	Fluoropolymers (PTFE) – nylons.	1
3.3	Polycarbonate – PVC – PE– PP – PS – polyurethanes.	1
3.4	Polycarbonate – PVC – PE– PP – PS – polyurethanes.	1
3.5	Thermosetting plastics – epoxy – phenol formaldehyde – urea	1

	formaldehyde.	
3.6	Polyesters – silicones, Bioplastics- Poly lactic acid.	1
3.7	Elastomers-Natural rubber- Butyl rubber- Nitrile rubber.	1
	MODULE IV (7 hours)	
4.1	Properties of polymers – rheology- – apparent viscosity - viscous flow - stress strain behaviour of elastomers.	1

4.2	Properties of polymers – rheology- – apparent viscosity - viscous flow - stress strain behaviour of elastomers.	1
4.3	Measurement of rheological properties – melt flow index (MFI) – capillary rheometers.	1
4.4	Testing of tensile strength, flexural strength, hardness and impact strength of polymers.	1
4.5	Testing of tensile strength, flexural strength, hardness and impact strength of polymers.	1
4.5	Effect of additives used; plasticizers; colourants, antioxidants; ultraviolet absorbers and heat stabilizers.	1
4.6	Effect of additives used; antioxidants, heat stabilizers.	1
4.7	Effect of additives used; antioxidants, heat stabilizers.	1
	MODULE V (7 hours)	
5.1	Injection moulding – compression moulding.	1
5.2	Injection moulding – compression moulding.	1
5.3	Calendaring – blow moulding- Extrusion – thermoforming.	1
5.4	Calendaring – blow moulding- Extrusion – thermoforming.	1
5.5	Wet, dry and melt spinning methods for fibers.	1
5.6	Vulcanization of rubber -General study of elastomer processing methods.	1

5.7	Introduction to nanocomposites	1

CO Assessment Sample Questions	
1	List the types of polymerisation based on thermal response with examples.
2	Give details of determining the molecular weight of polymers by solution viscosity.
3	Compare the properties of butyl and nitrile rubbers.
4	Describe different models of viscoelastic behaviour of polymers.
5	Describe the process of vulcanization of rubber.

24CHE694	BIOREACTOR ANALYSIS AND DESIGN	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: This course introduces the state of the art in bioreactor technology, its broad range of applications and strengthening the knowledge on analyzing bioreactor performance. It will also provide an understanding of the basic principles of the design of reactors for bioprocesses, develop mathematical descriptions of reaction kinetics and their relationships with reactor design and use them to analyze their behaviour.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Explain the functional description and working of conventional and novel bioreactors.
CO2	Calculate the batch reaction time and total batch time for enzymatic reactions.
CO3	Estimate theoretical design parameters in flow reactors.
CO4	Describe the theoretical and mechanical design aspects of bioreactors.
CO5	Explain the non-ideality of bioreactors using RTD studies.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	3	2										2
CO 2	3	2										2
CO 3	3	2	2									2
CO 4	3		3									2
CO5	3	2										2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	□	□	□	□
Understand	□	□	□	□
Apply	□	□	□	□
Analyse			□	
Evaluate			□	
Create			□	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	**5**	**15**	**10**	**10**	**40**

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Bioreactors - Function, description, working, advantages and limitations

Conventional Bioreactors - Stirred tank, airlift, airlift pressure cycle bioreactor, packed bed, fluidized bed, trickle bed and flocculated cell bioreactors. Novel Bioreactors - inverse fluid flow units, hollow fibre reactors, centrifugal field reactors, rotating drum bioreactor, spin filter bioreactor, disposable culture systems and wave bioreactor.

MODULE II: Batch Bioreactors

Batch bioreactor, cell death in batch reactor, endogenous metabolism, maintenance, calculation of batch reaction time from ideal system for enzyme reaction and cell culture, batch reaction time with enzyme deactivation, calculation of total batch time.

MODULE III: Continuous Flow Bioreactors

Ideal continuous flow stirred tank bioreactor (CFSTBR) - chemostat, substrate conversion and biomass productivity, mean residence time, comparison of batch bioreactor and single stage CFSTBR, washout condition, stability of the chemostat, chemostat with cell recycle, comparison of steady state biomass concentration and volumetric biomass productivity for a chemostat with and without cell recycle, conversion and productivity, Plug flow tubular reactor (PFTR).

MODULE IV: Design aspects of bioreactors

Guidelines for bioreactor design, bioreactor geometry, bioreactor vessels, agitator assembly, rheology and mixing, design, operation and types of agitators, power requirements for agitation, effects of agitation on mass transfer, oxygen delivery system - spargers, foam control system, mass transfer between phases – factors affecting mass transfer between phases.

MODULE V: Concept of non-ideal reactors

Residence time distribution, E(t) or F(t) and the bioreactor design, models of non-ideal reactors - Plug flow tubular reactor (PFTR), comparison of ideal mixed flow (batch and CFSTBR) and plug flow tubular reactors, calculation of reactor length and residence time, recycling in PFTRs, analysis of recycle reactor.

Text books

1. Pauline M Doran, Bioprocess Engineering Principles, Academic Press, 2013.
2. D G Rao, Introduction to Biochemical Engineering, Tata McGraw Hill, 2006.
3. Tapobrata Panda, Bioreactors: Analysis and Design, Tata McGraw-Hill Education, 2011.

Reference books

1. Alan H Scragg, Bioreactors in Biotechnology - A Practical Approach, Ellis Horwood, 1991.
2. Klaas van't Riet, Johannes Tramper, Basic Bioreactor Design, Marcel Dekker, 1991.
3. Douglas S Clark, Harvey W Blanch, Biochemical Engineering, 2/e, Marcel Dekker, 1997.
4. J E Bailey, D F Ollis, Biochemical Engineering Fundamentals, 2/e, McGraw-Hill Chemical Engineering Series, 1986.
5. Octave Levenspiel, Chemical Reaction Engineering, 3/e, Wiley Student Education, 2006.
6. H Scott Fogler, Essentials of Chemical Reaction Engineering, Pearson Education, 2011.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE 1 (8 hours)		
1.1	Conventional Bioreactors - Stirred tank bioreactors - Functional components.	1
1.2	Airlift, airlift pressure cycle bioreactor.	1
1.3	Packed bed, fluidized bed, trickle bed bioreactors.	1
1.4	Flocculated cell bioreactors	1
1.5	Novel Bioreactors - inverse fluid flow units.	1
1.6	Hollow fibre reactors, centrifugal field reactors.	1
1.7	Rotating drum bioreactor, spin filter bioreactor.	1
1.8	Disposable culture systems and wave bioreactor.	1
MODULE II (8 hours)		
2.1	Batch reactor, Kinetics of cell growth.	1
2.2	Substrate utilization and product formation.	1
2.3	Cell death in batch reactor, endogenous metabolism, maintenance.	1
2.4	Calculation of batch reaction time from ideal system for enzyme reaction and cell culture.	1
2.5	Calculation of batch reaction time from ideal system for enzyme reaction and cell culture.	1
2.6	Batch reaction time with enzyme deactivation.	1
2.7	Components of total batch time	1
2.8	Calculation of total batch time.	1
MODULE III (8 hours)		
3.1	Ideal continuous flow stirred tank bioreactor (CFSTBR) – chemostat	1

3.2	Multiple steady state analysis, mean residence time.	1
3.3	Biomass productivity, maximum biomass productivity.	1
3.4	Comparison of batch bioreactor and single stage CFSTBR.	1
3.5	Washout condition, stability of the chemostat, Numerical problems.	1
3.6	Chemostat with cell recycle, comparison of steady-state biomass concentration and volumetric biomass productivity for a chemostat with and without cell recycle.	1
3.7	Plug flow tubular reactor (PFTR).	1
3.8	Conversion and productivity.	1
MODULE IV (5 hours)		
4.1	Guidelines for bioreactor design, bioreactor geometry, bioreactor vessels.	1
4.2	Rheology and mixing, design, operation.	1
4.3	Types of agitators, power requirements for agitation.	1
4.4	Effects of agitation on mass transfer, oxygen delivery system – spargers, Foam control system.	1
4.5	Mass transfer between phases- Factors affecting mass transfer between phases.	1
MODULE V (7 hours)		
5.1	Non-ideality in reactors, non-ideality in batch bioreactors.	1
5.2	Residence time distribution, E(t) or F(t) and the bioreactor design.	1
5.3	Models of non-ideal reactors –Tanks in Series Model.	1
5.4	Dispersion Model.	1
5.5	Comparison of ideal mixed flow (batch and CFSTBR) and plug flow tubular reactors- residence time.	1

5.6	Recycling in PFTBR	1
5.7	Analysis of recycle reactors	1

CO Assessment Sample Questions	
1	Describe on the functional components of a bioreactor.
2	A strain of bacteria has been genetically engineered to produce protein. A batch culture is started by inoculating 15 g of cells into 80-litre batch stirred fermenter containing 10 g/l glucose. The culture immediately adapts to the environment so that it can be assumed that the system does not exhibit a lag phase. The cell maintenance requirement can be neglected. Also, there are no extra cellular products formed. The maximum specific growth rate of the cells is 1 h -1. The biomass yield from glucose is 0.6 g/g. i. Obtain the expression for batch growth time of this culture. ii. What will be time taken to reach the substrate concentration to 75% of the initial value?

	iii. If a downtime of 25 hours is expected between batches, how many batches could be processed in a year?
3	A 5 m3 fermenter is operated continuously using a feed substrate concentration of 20 kg/m3. The microorganism cultivated in the reactor has the following characteristics: μ_{max} = 0.45 h-1; KS = 0.8 kg/m3; YX/S = 0.55 kg/kg. i. Obtain the residence time of this chemostat? ii. What feed flow rate is required to achieve 90% substrate conversion? iii. How does the biomass productivity at 90% substrate conversion compare with the maximum possible.
4	Describe on the stepwise procedure for bioreactor vessel wall design.
5	Explain non-ideality of different bioreactors using RTD concepts.

SIXTH SEMESTER

PROFESSIONAL ELECTIVE-2 / INDUSTRIAL ELECTIVE

24CHE615	WATER AND WASTEWATER ENGINEERING	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: This course gives an overall information about the sources and demand of water and its physico-chemical and biological characteristic, treatment techniques to be carried out in day-to-day life. The wastewater generated from domestic and industrial sectors needs to be treated as per the guidelines defined by state and central regulatory bodies though engineered approach before final disposal to environment. This course will give an idea about the physico-chemical and biological treatment systems required for the wastewater in line with the disposal criteria defined by various regulatory bodies.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Estimate the quantity of water and wastewater by population forecasting methods and explain the physicochemical and biological characteristics.
CO2	Describe variou physical unit operations for wastewater treatment methods.
CO3	Select suitable biological unit process for wastewater treatment by aerobic process.
CO4	Explain the principle of anaerobic process to estimate the extend of treatment and explain tertiary wastewater treatment.
CO5	Describe sources and solid composition in sludge and its various treatment for sustainable disposal.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	3	3				3	3					2
CO 2	3	3				3	3					2
CO 3	3	3				3	3					2
CO 4	3	2				3	3					2
CO 5	3	2				3	3					2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	☐	☐	☐	☐
Understand	☐	☐	☐	☐
Apply	☐	☐	☐	☐
Analyse			☐	
Evaluate			☐	
Create			☐	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	**Attendance**	**Theory [L- T]**			**Total Marks**
		Assignment	**Test-1**	**Test-2**	
3-0-0-0	5	15	10	10	**40**

Total Mark distribution

Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 Hours

End Semester Examination [ESE]: Pattern

PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Water demand and its Treatment

Population forecast; Water demand for various purposes; Estimation of wastewater quantity. Variation in quantity of water and wastewater.
Water Supply/Distribution Systems. Wastewater Collection Systems. Philosophy of treatment; Unit operations and processes; Physical, chemical and biological methods Water Characteristics; Sequencing of unit operations and processes; (Surface and Ground Water Treatment for Potable Water Supply). Plant layout;
Hydraulic considerations.

MODULE II: Introduction to Wastewater Treatment

Domestic Wastewater Treatment, Wastewater characteristics; Primary, secondary and tertiary treatment. Physical Unit Processes: Screening; Comminutors and Macerators. Grit Removal: Conventional and aerated grit chambers. Equalization; Primary Sedimentation. Chemical Unit Processes: Coagulation Flocculation; Filtration; Disinfections; Aeration and Gas transfer; Precipitation; Softening;
Adsorption and Ion exchange; Membrane processes.

MODULE III: Aerobic Treatment of wastewater

Biological Unit Processes: Aerobic treatment; Suspended growth aerobic treatment processes. Activated sludge process, Design considerations. Activated sludge process and its modifications; Secondary clarifier design considerations. Attached growth aerobic processes; Tricking filters, High rate and low-rate trickling filters Rotating biological contactors (RBC). Oxidation Ponds: Aerobic, anaerobic and facultative ponds. Integrated Fixed-Film Activated Sludge (IFAS), Moving Bed
Biofilm Reactor (MBBR).

MODULE IV: Anaerobic Treatment and Tertiary treatment

Anaerobic treatment: Mechanism of anaerobic treatment of wastewater. Suspended growth process. Anaerobic treatment: Attached growth, fluidized bed and up-flow anaerobic sludge blanket (UASB) systems. Disinfection: Physical and Chemical methods.

Tertiary Wastewater Treatment: Filtration, Carbon Adsorption Chemical Phosphorous removal, Biological Phosphorus removal. Nitrogen Control:
Nitrification, denitrification, Ammonia stripping.

MODULE V: Sludge Treatment and disposal methods

Sludge Treatment: Sources and Characteristics of Various Sludges, Solids Computations. Thickening: Flotation, Gravity thickening, Stabilization: Aerobic and anaerobic sludge digestion. Sludge Conditioning: Chemical and Heat treatment. Sludge Dewatering: drying beds, continuous belt filter press (CBFP). Reduction: Incineration. Landfilling, Dedicated Land Disposal, Utilization, Land Application of
Biosolids, Sludge Disposal Regulations.

Text books

1. Mackenzie L. Davis, David A. Cornwell, Introduction toEnvironmental Engineering-McGraw Hill (2022)
2. Peavy, H.S., Rowe, D.R., and Tchobanoglous, G. Environmental Engineering, McGraw Hill International (1985)

Reference books

1. Nicholas P. Cheremisinof, Handbook of Water and Wastewater Treatment Technologies-Butterworth-Heinemann (2001).
2. C.S. Rao, Environmental Pollution Control Engineering, New Age International, (2007).
3. Metcalf and Eddy, Wastewater Engineering: Treatment and Reuse, 4th Edn., McGraw Hill Education India, (2004).

COURSE CONTENTS AND LECTURE SCHEDULE		
No.		No. of Hours
MODULE 1 (7 Hours)		
1.1	Population forecast; Water demand for various purposes; Estimation of wastewater quantity.	1
1.2	Variation in quantity of water and wastewater.	1
1.3	Water Supply/Distribution Systems.	1
1.4	Wastewater Collection Systems.	1
1.5	Philosophy of treatment; Unit operations and processes; Physical, chemical and biological methods	1
1.6	Water Characteristics; Sequencing of unit operations and processes; (Surface and Ground Water Treatment for Potable Water Supply).	1
1.7	Plant layout; Hydraulic considerations.	1
MODULE II (7 Hours)		
2.1	Domestic Wastewater Treatment, Wastewater characteristics; Primary, secondary and tertiary treatment.	1
2.2	Physical Unit Processes: Screening; Comminutors and Macerators.	1
2.3	Grit Removal: Conventional and aerated grit chambers.	1
2.4	Equalization; Primary Sedimentation.	1
2.5	Chemical Unit Processes: Coagulation Flocculation;	1
2.6	Filtration; Disinfections; Aeration and Gas transfer;	1
2.7	Precipitation; Softening; Adsorption and Ion exchange; Membrane processes	1
MODULE III (7 Hours)		

3.1	Biological Unit Processes: Aerobic treatment; Suspended growth aerobic treatment processes.	1
3.2	Activated sludge process, Design considerations	1
3.3	Activated sludge process and its modifications; Secondary clarifier design considerations.	1
3.4	Attached growth aerobic processes; Tricking filters, High rate and low-rate trickling filters	1
3.5	Rotating biological contactors (RBC)	1
3.6	Oxidation Ponds: Aerobic, anaerobic and facultative ponds	1
3.7	Integrated Fixed-Film Activated Sludge (IFAS), Moving Bed Biofilm Reactor (MBBR)	1
	MODULE IV (8 Hours)	
4.1	Anaerobic treatment: Mechanism of anaerobic treatment of wastewater	1
4.2	Suspended growth process	1
4.3	Anaerobic treatment: Attached growth, fluidized bed and up- flow anaerobic sludge blanket (UASB) systems.	1
4.4	Disinfection: Physical and Chemical methods	1
4.5	Tertiary Wastewater Treatment: Filtration, Carbon Adsorption	1
4.6	Chemical Phosphorous removal	1
4.7	Biological Phosphorus removal	1
4.8	Nitrogen Control: Nitrification, denitrification, Ammonia stripping	1
	MODULE V (6 Hours)	
5.1	Sludge Treatment: Sources and Characteristics of Various Sludges, Solids Computations.	1
5.2	Thickening: Flotation, Gravity thickening, Stabilization: Aerobic and anaerobic sludge digestion,	1
5.3	Sludge Conditioning: Chemical and Heat treatment	1
5.4	Sludge Dewatering: drying beds, continuous belt filter press (CBFP), Reduction: Incineration.	1

5.5	Landfilling, Dedicated Land Disposal, Utilization	1
5.6	Land Application of Biosolids, Sludge Disposal Regulations	1

<table>
<tr><th colspan="2">CO Assessment Sample Questions</th></tr>
<tr><td>1</td><td>The dissolved oxygen in an unseeded sample of diluted wastewater having an initial DO of 9.0 mg/L is measured to be 3.0 mg/L after 5 days. The dilution fraction is 0.03 and reaction rate constant k = 0.22 day^{-1}. Calculate (i) 5 day BOD of the waste, (ii) ultimate BOD, and (iii) remaining
oxygen demand after 5 days.</td></tr>
<tr><td>2</td><td>With neat sketches, explain different types of screens used for wastewater filtration. Write and explain the equations to calculate head loss in
screening operations.</td></tr>
<tr><td>3</td><td>A town in Kerala is upgrading its primary WWTP to a secondary plant that can meet an effluent standard of 30 mg/L BOD5 and 30 mg/L suspended solids. Assuming that the BOD5 of the suspended solids may be estimated as equal to 65 % of the suspended solids concentration, design a completely mixed activated sludge system. The following data are available from the existing plant: Flow = 12960 m3/day; BOD5 = 84.0 mg/L, Assume MLVSS = 2000 mg/L. For bacterial growth constants assume the following values:
<table>
<tr><th>Parameter</th><th>Value</th></tr>
<tr><td>K_s</td><td>100 mg/L of BOD_5</td></tr>
<tr><td>μ_m</td><td>2.5 day^{-1}</td></tr>
<tr><td>k_d</td><td>0.050 day^{-1}</td></tr>
<tr><td>Y</td><td>0.5 mg VSS. mg^{-1} BOD_5 removed</td></tr>
</table></td></tr>
<tr><td>4</td><td>With a neat schematic diagram, explain the patterns of carbon flow and
energy flow in anaerobic digestion process.</td></tr>
<tr><td>5</td><td>Develop volume-mass relationship to estimate the quantity of sludge in wastewater treatment process.
Compare aerobic and anaerobic sludge stabilization.
Explain alternative sludge disposal techniques.</td></tr>
</table>

24CHI625	OCCUPATIONAL HEALTH & HYGIENE	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: Occupational health and industrial hygiene are integral components of workplace well-being**.** This course provides a comprehensive exploration of the core concepts, methodologies, and applications required to identify, assess and control occupational hazards. Furthermore, this course outlines the basics of first aid and gives a review of India's statutory framework for workplace safety and health.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Explain the functional units and activities of occupational health services.
CO2	Comprehend the diverse hazards that exist within workplace environments.
CO3	Apply appropriate strategies to control physical, chemical and biological hazards in workplaces.
CO4	Develop legal documentation for safety compliance.
CO5	Apply principles of first aid to diverse emergency scenarios.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2			3				2		2
CO2	3	3	3			3				2		2
CO3	3	3	3			3				2		2
CO4	3	3	3			3		2		2		2
CO5	3	3	2			3				2		2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	☐	☐	☐	☐
Understand	☐	☐	☐	☐
Apply	☐	☐	☐	☐
Analyse			☐	
Evaluate			☐	
Create			☐	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	**Attendance**	**Theory [L- T]**			**Total Marks**
		Assignment	**Test-1**	**Test-2**	
3-0-0-0	5	15	10	10	**40**

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 hours

End Semester Examination [ESE]: Pattern

PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Introduction to occupational health and Legislative frame work of OSH in India

Concept and spectrum of health- functional units and activities of occupational health services- National and International Organizations in the field of occupational health-Overview of ISO 45001-Occupational Safety Health and Working Conditions Code 2020:Notifyiable diseases as per the code: their effects and prevention-Occupational safety and health standards- Safety and occupational health surveys-Safety officer and safety committee-National Occupational Safety and health advisory board-State Occupational Safety and health advisory board- Inspector cum Facilitators: Appointment and powers-Offenses and penalties under Occupational safety Health and Working Conditions Code 2020.

MODULE II: Recognition and evaluation of Physical hazards

Noise- noise measurement and evaluation -hearing loss – causes -Biological effects of noise exposure. Thermal stress – heat disorders and health effects such as heat exhaustion, hear cramp etc. WBGT index, acclimatization. Vibration –description and measurement of vibration. Vibration control methods. Effects of whole-body vibration on human body and control measures. Ionizing and non-ionizing radiation: hazards and controlling measures- Instruments for Radiation detection and measurement. Purpose of lighting. Advantages of good illumination. Lighting and the work- Standards on lighting and illuminations.

MODULE III: Recognition and evaluation of chemical hazards

Hazardous chemicals: Definition and characteristics-NFPA diamond-MSDS- HAZCHEM code-TREM card-UN classification of hazardous chemicals- Routes of entry of hazardous substances into the body-Effects of toxicants on biological organisms-Toxicological studies- Dose vs Response- Models for dose and response- Threshold limit values-Evaluation of chemical hazards: Methods of Evaluation- process or operation description-Field Survey-Sampling methodology-Sampling instruments- Industrial Hygiene calculations.

MODULE IV: Biological hazards and Principles of First Aid

Classification of Bio hazardous agents –bacterial agents, rickettsial and chlamydial agents, viral agents, fungal, parasitic agents, infectious diseases -Control of biological hazards.

First Aid Principles-Statutory requirement of first aid in factories-Role of the first aider-sequence of action on arrival at scene. ABC of first aid- vital signs of life of an accident victim-CPR- Effect of electricity on human body and first aid-First aid for burns-Wounds and bleeding- Asphyxia-Unconsciousness and shock- Skeletal injuries.

MODULE V: Control measures

Aims of control-Hierarchy of control measures- Engineering controls: Ventilation systems - purpose of ventilation-general principles ventilation requirements- Physiological and comfort level. Natural ventilation - Dilution ventilation - Mechanical ventilation - Local exhaust ventilation - Ventilation measuring instruments. Fundamentals of hood and duct designs. Standards on ventilation- Respirators: Various types of respirators useful to chemical industry.
Text books 1. Daniel A Crowl & Joseph F Louvar, Chemical Process Safety, Second Edition, Prentice-Hall.

2. Sam Mannan, Lees' Loss Prevention in the Process Industries: Hazard Identification, Assessment and Control, Vol: 1-3-Butterworth-Heinemann (2004). 3. Barbara A. Plog, Patricia J. Quinlan, Fundamentals of Industrial Hygiene (5th edition), National Safety Council Chicago,5th Edition (2001) 4. Frank R. Spellman, Industrial Hygiene Simplified-A Guide to Anticipation, Recognition, Evaluation, and Control of Workplace Hazards-Government Institutes (2006).
Reference books 1. Jeanne Mager Stellman (ed). Encyclopedia of occupational health and safety. (Four volumes). (Fourth edition). International Labour Office, Geneva. (1998). 2. The industrial environment - its evaluation and control. DHHS (NIOSH) publication number 74-117, (1973). 3. Clayton, C.D. and Clayton, F. Patty's industrial hygiene and toxicology. Wiley New York. (1981). 4. Gayle Woodside & Dianna Kocurek, Environmental, Safety and Health Engineering, John Wiley & Sons, New York, (1997). 5. Cantlie, James. First aid to the injured. St John Ambulance Association. (1932). 6. Yudenich, V.V. Accident first aid, Mir Publishers, Moscow. (1986). 7. The Occupational Safety Health and Working Conditions Code 2020, Commercial Law Publishers (India) Pvt.Ltd., New Delhi.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1 (7 hours)	
1.1	Concept and spectrum of health-functional units and activities of occupational health services	1
1.2	National and International Organizations in the field of occupational health	1

1.3	Overview of ISO 45001	1
1.4	Occupational Safety Health and Working Conditions Code 2020: Notifiable diseases as per the code: their effects and prevention.	1
1.5	Occupational safety and health standards- Safety and occupational health surveys	1
1.6	Safety officer and safety committee-National Occupational Safety and health advisory board- State Occupational Safety and health advisory board	1
1.7	Inspector cum Facilitators: Appointment and powers- Offenses and penalties under Occupational safety Health and Working Conditions Code 2020.	1
	MODULE II (8 hours)	

2.1	Noise- noise measurement and evaluation	1
2.2	hearing loss – causes - Biological effects of noise exposure	1
2.3	Thermal stress – heat disorders and health effects such as heat exhaustion, hear cramp etc. WBGT index, acclimatization	1
2.4	Vibration –description and measurement of vibration	1
2.5	Vibration control methods. Effects of whole-body vibration on human body and control measures	1
2.6	Ionizing and non-ionizing radiation: hazards and controlling measures.	1
2.7	Instruments for Radiation detection and measurement	1
2.8	Purpose of lighting. Advantages of good illumination. Lighting and the work- Standards on lighting and illuminations.	1
	MODULE III (8 hours)	
3.1	Hazardous chemicals: Definition and characteristics-NFPA diamond-MSDS- HAZCHEM code-TREM card-UN classification of hazardous chemicals	1
3.2	Routes of entry of hazardous substances into the body-Effects	1

	of toxicants on biological organisms	
3.3	Toxicological studies- Dose vs Response	1
3.4	Models for dose and response- Threshold limit values	1
3.5	Evaluation of chemical hazards: Methods of Evaluation- process or operation description	1
3.6	Field Survey-Sampling Methodology-Sampling instruments	1
3.7	Industrial Hygiene calculations.	1
3.8	Industrial Hygiene calculations.	1
MODULE IV (6 hours)		
4.1	Classification of Bio hazardous agents –bacterial agents, rickettsial and chlamydial agents	1
4.2	viral agents, fungal, parasitic agents, infectious diseases	1
4.3	Control of biological hazards	1
4.4	First Aid Principles-Statutory requirement of first aid in factories-Role of the first aider-sequence of action on arrival at scene. ABC of first aid	1
4.5	Vital signs of life of an accident victim-CPR-Effect of electricity on human body and first aid	1
4.6	First aid for burns-Wounds and bleeding- Asphyxia- Unconsciousness and shock- Skeletal injuries.	1
MODULE V (6 hours)		
5.1	Aims of control-Hierarchy of control measures	1
5.2	Ventilation systems - purpose of ventilation-general principles ventilation requirements- Physiological and comfort level	1
5.3	Natural ventilation - Dilution ventilation - Mechanical ventilation - Local exhaust ventilation - Ventilation measuring instruments.	1
5.4	Fundamentals of hood and duct designs.	1
5.5	Fundamentals of hood and duct designs.	1
5.6	Standards on ventilation-Respirators: Various types of respirators useful to chemical industry.	1

CO Assessment Sample Questions	
1	Discuss the functional units and activities of occupational health services.
2	Air contains 5 ppm of diethylamine (TLV-TWA of 5 ppm), 20 ppm of cyclohexanol (TLV-TWA of 50 ppm), and 10 ppm of propylene oxide (TLV- TWA of 2 ppm). Find the mixture TLV-TWA. Are the workers overexposed under these conditions?
3	An open vessel of 1 m in diameter and 2 m tall is being splash-filled with ethyl acetate ($C_4H_8O_2$) liquid. The vessel takes 30 min to fill. The local ventilation rate is 0.50 m^3/s. a. Estimate the local concentration (in ppm) of ethyl acetate. Compare to the TLV. b. Estimate the local concentration (in ppm) if the vessel is covered with a flat metal sheet and the filling is done through a 5-cm-diameter hole. Compare to the TLV. c. Which filling method do you recommend and why? For both cases T = 25°C and the ambient pressure is 1 atm. The specific gravity of the ethyl acetate is 0.90.
4	Discuss the powers of the inspector appointed for the purpose of administration of provisions under Occupational Safety Health and Working Conditions Code 2020.
5	Discuss the process of CPR and its importance.

		L	T	P	J	S	C	Year of Introduction
24CHE635	**OPTIMIZATION OF CHEMICAL PROCESSES**	**3**	**0**	**0**	**0**	**3**	**3**	**2024**

Preamble: Process optimization is a discipline to evaluate the best possible values of process or process sub-system variables to improve its efficiency by applying analytical and numerical methods. This course aims to familiarize the students with techniques, which are frequently applied to optimize process or process sub-system variables. It also provides a detailed computational approach to analyze and design any chemical process, where such an approach is appropriate.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Identify the importance and values of mathematical modelling and process optimization.
CO2	Formulate linear and non-linear programming models.
CO3	Solve basic chemical engineering problems using linear and non-linear optimization techniques and algorithms
CO4	Solve various multivariable optimization problems.
CO5	Apply different optimization techniques in chemical engineering process design.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3									2
CO2	3	3	3									2
CO3	3	3	3									2
CO4	3	3	3									2
CO5	3	3	3	3	3							2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	□	□	□	□
Understand	□	□	□	□
Apply	□	□	□	□
Analyse			□	
Evaluate			□	
Create			□	

Mark Distribution of CIA

		Theory [L- T]	

Course Structure [L-T-P-J]	Attendance	Assignment	Test-1	Test-2	Total Marks
3-0-0-0	5	15	10	10	**40**

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 Hrs

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub-divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Introduction to Process optimization & overview of mathematical functions

Scope and hierarchy of optimization, Typical chemical engineering applications of optimization. Statement of an Optimization Problem and its essential features, Classification of Optimization Problems and its essential features. Mathematical modelling of typical chemical engineering optimization problems. Nature and classification of mathematical functions, Graphical representation of univariate and bivariate functions (using MATLAB / Python, etc.). Unimodal functions, determination of convexity and concavity of single and multivariate functions.

MODULE II: Analytical & Numerical methods for unconstrained optimization problems

Analytical methods: Necessary and sufficient conditions for optimum univariate unconstrained functions. Numerical methods: One-dimensional gradient-free search methods (Fixed & accelerated step size, Dichotomous search, Fibonacci search, golden- section method, and quadratic interpolation), One-dimensional gradient search methods

(Newton's method, and Quasi-Newton method).

MODULE III: Analytical methods for constrained multivariate optimization problems

Nonlinear programming with equality constraints: method of direct substitution, Lagrange multiplier method, Nonlinear programming with inequality constraints: Kuhn-Tucker conditions for local optimality, Complex method, Rosen's gradient projection method.

MODULE IV: Numerical methods for unconstrained & constrained multivariate optimization problem

Unconstrained multivariate optimization problems: Univariate search, Powell's method, method of steepest descent, Fletcher-Reeve's conjugate-gradient method, Newton's method. Constrained multivariate optimization problems: Basic concepts and graphical representation of Linear programming, graphical solution, Simplex method, and two-phase simplex method.

MODULE V: Optimization case studies in chemical engineering

Economic considerations: Capital cost, operating cost, raw material cost, processing cost etc., Various measures of profitability. Problems solvable analytically: Minimize the capital cost of cylindrical pressure vessel with flat and closed ends-Optimum thermal insulation thickness for cylindrical pipe, Optimum intermediate concentration and time of reaction for series reaction in batch reactors, Optimum pipe diameter for an incompressible fluid, Minimum work done on two and three-stage compressor for isentropic compression of ideal gas. Problems solvable numerically: Optimum reflux ratio for a staged-distillation column, fitting vapor-liquid equilibrium data using nonlinear regression, optimum design of shell-and-tube heat exchanger, optimization of a thermal cracker using linear programming.

Textbooks

1. Edgar T. F., Himmelblau D. M., "Optimisation of Chemical Processes", McGraw Hill.
2. Rao S.S., "Optimization: Theory and Applications", Wiley Eastern.

Reference books

1. Louis Theodore and Kelly Behan, "Introduction to Optimization for Environmental and Chemical Engineers", CRC press.
2. Rajesh Kumar Arora, "OPTIMIZATION Algorithms and Applications", CRC press
3. Philip D.T. and Ravindran A., "Operations Research", John Wiley.
4. Beightler C.S., Phillips D.T. & Wilde D.J., Foundations of Optimization, Prentice Hall of India
5. Beveridge G.S.G. & Schechter R.S., Optimization: Theory & Practice, McGraw Hill

COURSE CONTENTS AND LECTURE SCHEDULE		
No.		No. of Hours
	MODULE 1 (8 hours)	
1.1	Scope and hierarchy of optimization.	1
1.2	Statement of an Optimization Problem and its essential features.	1
1.3	Nature and classification of mathematical functions.	1
1.4	Typical chemical engineering applications of optimization. Mathematical modelling of typical chemical engineering optimization problems.	1
1.5	Typical chemical engineering applications of optimization. Mathematical modelling of typical chemical engineering optimization problems.	1
1.6	Graphical representation of univariate and bivariate functions (using MATLAB / Python etc).	1
1.7	Unimodal functions, determination of convexity and concavity of single and multivariate functions.	1
1.8	Unimodal functions, determination of convexity and concavity of single and multivariate functions.	1
	MODULE II (7 hours)	
2.1	Analytical methods: Necessary and sufficient conditions for optimum of univariate unconstrained functions.	1
2.2	Numerical methods: one-dimensional gradient-free search methods (Fixed & accelerated step size).	1
2.3	Numerical methods: Dichotomous search method.	1
2.4	Numerical methods: Fibonacci search method.	1
2.5	Numerical methods: golden-section method and quadratic interpolation.	1
2.6	Numerical methods: golden-section method and quadratic interpolation.	1

2.7	One-dimensional gradient search methods (Newton's method and Quasi-Newton method).	1
MODULE III (6 hours)		
3.1	Nonlinear programming with equality constraints: method of direct substitution.	1
3.2	Nonlinear programming with equality constraints: Lagrange multiplier method.	1
3.3	Nonlinear programming with inequality constraints: Kuhn-Tucker conditions for local optimality.	1
3.4	Nonlinear programming with inequality constraints: Kuhn-Tucker conditions for local optimality.	1
3.5	Complex method.	1
3.6	Rosen's gradient projection method.	1
MODULE IV (7 hours)		
4.1	Unconstrained multivariate optimization problems: univariate search, Powell's method.	1
4.2	Constrained multivariate optimization problems: method of steepest descent.	1
4.3	Fletcher-Reeve's conjugate-gradient method.	1
4.4	Newton's method.	1
4.5	Basic concepts and graphical representation of Linear programming, graphical solution.	1
4.6	Simplex method and two-phase simplex method.	1
4.7	Simplex method and two-phase simplex method	1
MODULE V (8 hours)		
5.1	Economic considerations	1
5.2	Minimize the capital cost of cylindrical pressure vessel with flat and closed ends, optimum thermal insulation thickness for cylindrical pipe.	1
5.3	Optimum intermediate concentration and time of reaction for series reaction in batch reactor, Optimum pipe diameter for an incompressible fluid.	1
5.4	Minimum work done on two and three-stage compressors for isentropic compression of ideal gas.	1
5.5	Problems solvable numerically: Optimum reflux ratio for a staged- distillation column.	1
5.6	Fitting vapor-liquid equilibrium data using nonlinear regression.	1
5.7	Optimum design of shell-and-tube heat exchanger.	1

5.8	Optimization of a thermal cracker using linear programming.	1

CO Assessment Sample Questions	
1	Classify the general optimization problems. State the essential features of optimization problems.
2	Define unimodal function with a mathematical statement. Give a graphicalrepresentation.
3	Find the minimum of f(x)= x(x-5π) by one iteration using Quasi-Newton's method with initial point 2 and step size 0.01
4	A toy manufacturing organization manufactures two types of toys A and B. Both the toys are sold at Rs.25 and Rs.20 respectively. There are 2000 resource units available every day from which toy A requires 20 units while toy B requires 12 units. Both of these toys require a production time of 5 minutes. Total working hours are 9 hours a day. Formulate and solve the optimization problem to maximize the profits.
5	Formulate the mathematical equations to find the Optimum thermal insulation thickness for the cylindrical pipe.

24CHI645	PETROLEUM REFINING AND PETROCHEMICAL TECHNOLOGY	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: This course introduces students to the concepts of petroleum refinery operations that are used for applications in chemical engineering. This course summarizes various petroleum refinery operations like preliminary, primary and secondary. It also explains the classification and evaluation of crude oil, treatments of petroleum products their properties, applications and test methods.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Review the origin, various exploration and recovery methods of crude oil.
CO2	Outline the modern integrated petroleum refinery, its feedstock, products and the process employed.
CO3	Summarize different petroleum based products and their uses.
CO4	Explain refining process covering operating description and conditions,feedstock and catalyst selection, product yield and the relation between different process parameters.
CO5	Differentiate between petroleum and petrochemical products and explain various petrochemical products, their manufacture and uses.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	3					2	2					2
CO 2	3					2	2					2
CO 3	3						2					2
CO 4	3					2	2					2
CO 5	3					2	2					2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	☐	☐	☐	☐
Understand	☐	☐	☐	☐
Apply	☐	☐	☐	☐
Analyse			☐	
Evaluate			☐	
Create			☐	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3

<u>**End Semester Examination [ESE]: Pattern**</u>

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Origin and composition

Origin and formation of crude oil. Oil exploration and drilling. Storage and transportation of crude oil and products. Classification, Composition and Evaluation of oil stock. Status of Petroleum industry in India. Classification of petroleum refinery.

MODULE II: Preliminary processing and Primary refinery operations

Preliminary petroleum processing-Impurities in crude oil, Dehydration and desalting of crude-Electric Desalter-, Process description, factors affecting the electric desalter. Pipe still furnaces and its operations. Distillation of crude- Prefractionator, Atmospheric topping unit, Vacuum distillation unit.

MODULE III: Catalytic conversion and quality upgradation

Thermal Conversion process: Process description of Thermal cracking, Visbreaking, Coking (delayed coking). Process description and process variables of catalytic cracking, Process description and process variables of fluid Catalytic cracking unit. Process description and applications of Hydro cracking. Process description of catalytic reforming. Process description of alkylation process- sulphuric acid alkylation. Process description of isomerization process.

MODULE IV: Treatment of gasoline

Treatment of gasoline- Copper Chloride process and Merox sweetening. Production and treatment of L.P.G. Diesel Hydro desulphurisation (DHDS) and production of Ultra low sulphur Diesel (ULSD), Bharath stage norms of Diesel and Gasoline. Production and treatment of Lube- Phenol extraction. Properties, test methods and uses of Refinery products such as L.P.G, Gasoline, Jet fuel, Kerosene, Diesel fuel, Lube oil and Bitumen.

MODULE V: Petrochemicals

Classification of petrochemicals: light, medium and heavy, Manufacture of Methanol from Synthesis Gas, manufacture of formaldehyde from methanol, manufacture of Low density polyethylene (LDPE) and high density polyethylene (HDPE). Manufacture of Benzene, Toluene and Xylene by catalytic reforming.

Text books

1. Baskara Rao B.K, Modern Petroleum Refinery Process, Oxford& IBM
2. Dr.Ram Prasad, Petroleum Refining Technology, Khanna Publishers
3. Dryden C. E., Outlines of Chemical Technology, East-West Press, 2008
4. M. Wells, Handbook of Petrochemicals and Processes, 2nd Ed., Ashgate Publishing Co., 1999.

Reference books

1. Uttam Ray Chaudhuri, Fundamentals of Petroleum and Petrochemical Engineering, CRC Press
2. Dr.Kochu Baby Manjooran S, Modern Petroleum Chemistry.
3. James H.Garry Glenn E. Handwerk Mark J.Kaiser, Petroleum Refinery Technology and Economics, CRC Press, Taylor and Francis group.
4. I D Mall, Petrochemical Process technology, Macmillan
5. Nelson W.L, Petroleum Refinery Engineering, McGraw Hill
6. Gopala Rao M & Sitting M, Drydens Outline of Chemical Technology, Affiliated East West Press

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE 1 (6 hours)		
1.1	Origin and formation of crude oil.	1
1.2	Oil exploration and drilling.	1
1.3	Storage and transportation of crude oil and products.	1
1.4	Classification, Composition and Evaluation of oil stock.	1
1.5	Status of Petroleum industry in India.	1
1.6	Classification of petroleum refinery.	1
MODULE II (6 hours)		
2.1	Preliminary petroleum processing-Impurities in crude oil	1
2.2	Dehydration and desalting of crude-Electric Desalter-, Process description, factors affecting the electric desalter.	1
2.3	Pipe still furnaces and its operations.	1
2.4	Distillation of crude- Prefractionator	1
2.5	Atmospheric topping unit	1
2.6	Vacuum distillation unit.	1

MODULE III (8 hours)		
3.1	Thermal Conversion process: Process description of Thermal cracking, Visbreaking,	1
3.2	Process description of Coking (delayed coking).	1
3.3	Process description and process variables of catalytic cracking,	1
3.4	Process description and process variables of fluid Catalytic cracking unit.	1
3.5	Process description and applications of Hydro cracking.	1
3.6	Process description of catalytic reforming.	1
3.7	Process description of alkylation process- sulphuric acid alkylation.	1
3.8	Process description of isomerization process.	1
MODULE IV (7 hours)		
4.1	Treatment of gasoline- Copper Chloride process and Merox sweetening.	1
4.2	Production and treatment of L.P.G. Diesel Hydro desulphurisation (DHDS)	1
4.3	Production of Ultra low sulphur Diesel (ULSD),	1
4.4	Bharath stage norms of Diesel and Gasoline.	1
4.5	Production and treatment of Lube- Phenol extraction.	1
4.6	Properties, test methods and uses of Refinery products such as L.P.G, Gasoline, Jet fuel, Kerosene.	1
4.7	Properties, test methods and uses of Refinery products such as Diesel fuel, Lube oil and Bitumen.	1
MODULE V (8 hours)		
5.1	Classification of petrochemicals: light, medium and heavy.	1
5.2	Manufacture of Methanol from Synthesis Gas	1

5.3	Manufacture of formaldehyde from methanol	1
5.4	Manufacture of Low density polyethylene (LDPE)	1
5.5	Manufacture of and high density polyethylene (HDPE).	1
5.6	Manufacture of Benzene by catalytic reforming.	1
5.7	Manufacture of Toluene by catalytic reforming.	1
5.8	Manufacture of Xylene by catalytic reforming.	1

CO Assessment Sample Questions	
1	Differentiate geophysical and geochemical prospecting and explain any four types of geophysical prospecting techniques for oil exploration.
2	Explain atmospheric distillation of crude oil with a simplified flow diagram.
3	Describe the properties and uses of any three petroleum products.
4	A chemical process is used to convert straight run naphtha distilled from crude oil into high octane liquid products which are premium blending stocks for high octane gasoline. Explain the process with a neat sketch and mention the catalysts used.
5	With a neat flowsheet, explain the manufacture of Methanol from Synthesis Gas.

24CHI655	PROCESS PLANT UTILITIES	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: The course focuses on understanding the important technical fundamentals of chemical process plant utilities. The course covers process utility systems, fuels and compressed air systems, process steam systems, piping networks, valves & pumps, refrigeration, ventilation and air conditioning systems. The emphasis on the fundamentals will help the student to understand the concepts and apply them accordingly.

Prerequisite: Nil.

Course Outcomes: After the completion of the course the student will be able to

CO 1	Describe major types, processes and associated equipments of utility systems employed in industries.
CO 2	Compute the power rating of equipments and select the rating of instruments and process auxiliaries.
CO 3	Perform mathematical calculations involved in steam generation, psychrometry and refrigeration operations.
CO 4	Explain different types of compressors, valves, pumps, and their requirements in process industries.
CO 5	Perform piping network design and describe process control and instrumentation diagram and its applicability.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	3	2	1									2
CO 2	3	3	3									2
CO 3	3	1	3									2
CO 4	3	1	1									2
CO 5	3	2	1									2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	☐	☐	☐	☐
Understand	☐	☐	☐	☐
Apply	☐	☐	☐	☐
Analyse			☐	
Evaluate			☐	
Create			☐	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	**40**

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Process utility systems

Process Utility Systems: Classification of process utility systems, Importance of process utilities in chemical industries and plants. Water as a utility in process industries: Sources of water, hard and soft water, requisites of industrial water and its uses, methods of water treatment, storage and distribution of water, recycle and conservation of water. Cooling Tower: Types and performance evaluation.

MODULE II: Fuels and compressed air systems

Introduction to Fuels: Types, Proximate and ultimate analysis, Calorific value and its calculation. Compressed air system: Types, construction and working: Reciprocating (Single and double), centrifugal and gear compressors, fans and blowers. Power requirement and performance calculations. Vacuum Systems: Basic Concepts of vacuum and pressure, Components of vacuum system like vacuum chamber, pumps, gauges, valves, seals, and many other subsidiary components., Vacuum generation and Piping.

MODULE III: Process Steam systems

Steam System: Steam and its importance, Properties of steam, Problems based on enthalpy calculation for wet steam, dry saturated steam and superheated steam. Boilers: Types of steam generators/boilers, Fire tube boilers and water tube boilers, examples, boiler mountings and accessories, boiler performance and its calculation, Analysis of losses, leakage test, Energy conservation opportunities, Boilers Act. Steam handling and distribution: Steam distribution system, Steam economy, Steam traps, Condensate and flash steam recovery system. Waste Heat Recovery:
Classification, commercially viable waste heat recovery devices, Saving potential.

MODULE IV: Piping networks, valves and pumps

Piping network design, Process control and instrumentation diagram. piping networks for water, steam, condensate and air. Colour codes for piping, Chilled Water Insulation Piping, Compressed Air Piping, Water Utility Piping, Cooling Coil Heat Transfer, Anti Fire Pipes and steam piping. Valves: Types of valves, selection criteria of valves for various systems. Pumps: Types of pumps, NPSH requirement.

MODULE V: Refrigeration and ventilation

Refrigeration and Ventilation: Principles of refrigeration, vapour compression and vapour absorption refrigeration cycles, types of refrigerants and their importance. Air conditioning: Air-conditioning system and its components. Insulation: Types of insulation, Selection criteria for insulating materials. Production of cryogenic temperatures. Characteristics of Air-water systems. Humidification and Dehumidification equipments. Exhaust & Ventilation.
Text books 1. F.C. Vibrandt and C.E. Dryden, “Chemical Engineering Plant Design”, McGraw Hill, Fifth Edition. 2. Jack Broughton; Process utility systems; Institution of Chem. Engineers, U.K. 3. M.S. Peters and Timmerhaus, “Plant design and Economics for Chemical Engineers”, Mc Graw Hill 3rd Edition. 4. Roger Hunt and Ed Bausbacher, “Process Plant layout and Piping Design” PTR Prentice-Hall Inc.

Reference books

1. Nordell,Eskel."Water Treatment for industrial and other uses" Reinhold Publishing Corporation, New York (1961).
2. Plant Utilities by Dr. Mujawar, Nirali Prakashan Publication.
3. Plant Utilities by D.B. Dhone, Nirali Prakashan Publication.
4. P.L.Balleney, Thermal Enginnering, Khanna Publisher, New Delhi.

COURSE CONTENTS AND LECTURE SCHEDULE		
No.		No. of Hours
	MODULE 1 (7 hours)	
1.1	Process Utility Systems: Classification of process utility systems.	1
1.2	Importance of process utilities in chemical industries and plants.	1
1.3	Water as a utility in process industries: Sources of water, hard and soft water.	1
1.4	Requisites of industrial water and its uses.	1
1.5	Methods of water treatment.	1
1.6	Storage and distribution of water, recycle and conservation of water.	1
1.7	Cooling Tower: Types and performance evaluation.	1
	MODULE II (8 hours)	
2.1	Introduction to Fuels: Types.	1
2.2	Proximate and ultimate analysis, Calorific value and its calculation.	1
2.3	Compressed air system: Types, construction and working.	1
2.4	Reciprocating (Single and double), centrifugal and gear compressors, fans and blowers.	1
2.5	Power requirement and performance calculations.	1
2.6	Vacuum systems: Basic Concepts of vacuum and pressure, Components of vacuum system like vacuum chamber.	1
2.7	Pumps, gauges, valves, seals, and many other subsidiary	1

	components.	
2.8	Vacuum generation and Piping.	1
MODULE III (8 hours)		

3.1	Steam System: Steam and its importance, Properties of steam.	1
3.2	Problems based on enthalpy calculation for wet steam.	1
3.3	Dry saturated steam and superheated steam.	1
3.4	Boilers: Types of steam generators/boilers, Fire tube boilers and water tube boilers, examples, boiler mountings and accessories.	1
3.5	Boiler performance and its calculation, Analysis of losses, leakage test, Energy conservation opportunities, Boilers Act.	1
3.6	Steam handling and distribution: Steam distribution system.	1
3.7	Steam economy, Steam traps, Condensate and flash steam recovery system, Identifying opportunities for energy savings.	1
3.8	Waste Heat Recovery: Classification, Advantages and applications, commercially viable waste heat recovery devices, Saving potential.	1
MODULE IV (6 hours)		
4.1	Piping network design.	1
	Process control and instrumentation diagram.	1
4.2	Piping networks for water, steam, condensate and air.	1
	Colour codes for piping, Chilled Water Insulation Piping, Compressed Air Piping.	1
4.3	Water Utility Piping, Cooling Coil Heat Transfer, Anti Fire Pipes and steam piping.	1
4.4	Valves: Types of valves, selection criteria of valves for various systems. Pumps: Types of pumps, NPSH requirement.	1
MODULE V (7 hours)		

5.1	Refrigeration and Ventilation: Principles of refrigeration. Vapour compression and vapour absorption refrigeration cycles.	1
5.2	Types of refrigerants and their importance. Air conditioning: Air-conditioning system and its components.	1
5.3	Insulation: Types of insulation, Different types of insulating materials and their characteristics, Selection criteria for insulating materials.	1
5.4	Production of cryogenic temperatures.	1
5.5	Characteristics of Air-water systems.	1
5.6	Humidification and Dehumidification equipments.	1
5.7	Exhaust & Ventilation.	1

CO Assessment Sample Questions	
CO1	Identify and describe the major types, processes and associated equipments of utility systems employed in industries. 1. State and explain any seven requirements of a good water distribution system. 2. Differentiate primary and secondary plant utility systems.
CO2	Compute the power rating of equipments and select the rating of instruments and process auxiliaries. 1. Classify different types of vacuum pumps and explain performance characteristics. 2. A single stage compressor is used to compress 800 m3 /hr of CO2 measured at 288 K and 1 bar from its initial stage of 0.5 bar and 300 K to a final pressure of 1.5 bars. A volumetric efficiency of 75 % and a compression efficiency of 85 % may be assumed. Assuming adiabatic compression, calculate the power required for driving the compressor, the piston displacement in m3 /s and the discharge temperature.

CO3	Perform mathematical calculations involved in steam generation, psychrometry and refrigeration operations. 1. Define Psychrometry? Enumerate and explain different psychrometric processes and represent them on a psychrometric chart. 2. Distinguish economy and capacity with respect to boilers? List and explain the different types of boilers used in chemical industry. 3. A refrigeration system has working temperature of –27°C and 37°C. Find out actual COP, if it is 70% of Maximum.
CO4	With a neat sketch, explain single acting reciprocating compressor? Differentiate reciprocating and rotary compressors.
CO5	1. State and explain some of the general considerations that should be evaluated when selecting and applying materials for piping. 2. List the types of piping networks for steam and briefly describe their applications.

24CHE665	FUEL CELL TECHNOLOGY	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: One of the most promising near-term technologies are those based on fuel cells, which convert chemical energy into electrical energy with higher efficiencies and far fewer environmental effects than other options. This course is intended to provide an insight into the fuel cell and focuses on developments made in the area and the challenges facing in its wide practical applications. The course also brings an overview on future prospects in the development and application of fuel cell.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to:

CO1	Summarize the fundamentals of thermodynamics, kinetics and transport in fuel cells
CO2	Compare different types of fuel cell systems
CO3	Calculate the various losses in fuel cells
CO4	Design a fuel cell stack for a given application
CO5	Distinguish the expectances of hydrogen as a fuel and energy vector in the context of renewable energy

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3										2
CO2	3	3										2
CO3	3	3										2
CO4	3	3	2									2
CO5	3	3										2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember		□	□	□
Understand		□	□	□
Apply		□	□	□
Analyse			□	
Evaluate			□	
Create			□	

Mark Distribution of CIA					
CourseStructure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 hours

End Semester Examination (ESE) Pattern:

PATTERN	PART A	PART B	ESE Marks
Pattern 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: 5 x 8 = 40	

SYLLABUS

MODULE I: Introduction to fuel cell technology

Fuel Cell and conventional processes – comparison; Types of Fuel Cells; Application scenarios; Advantages and disadvantages; Energy & power relations, Units; Working of a PEM fuel Cell - Major Cell Components, Material Properties, Processes and Operating
Conditions of PEMFC.

MODULE II: Thermodynamics and Reaction Kinetics

Thermodynamics: Gibb's free energy -Work potential of fuel; Reversible voltage - NERNST Equation, Voltage and P, T and concentration dependence – examples; Faraday's Laws; Efficiency: thermodynamic, voltage and fuel.

Reaction Kinetics: Electrochemical reaction fundamentals; electrode kinetics; Charge transfer and activations energy; Exchange current density - slow and fast reactions; Potential and equilibrium - galvanic potential; Reaction rate and potential - Butler

Volmer equation & Tafel equation; Exchange Currents and Electrocatalysis.

MODULE III: Charge and Mass Transport

Charge transport resistances; voltage losses; Ionic and electronic conductivities; Ionic conduction in different FC electrolytes: Aqueous, polymeric and ceramic; Diffusive transport & voltage loss: Limiting current density; Nernstian and kinetic effect; Convective transport: flow channels, gas diffusion / porous layer, gas velocity, pressure.

MODULE IV: Stack Design and Fuel Cell Diagnostics

Stack Design: Sizing of a Fuel Cell Stack; Stack Configuration; Uniform distribution of Reactants; Heat removal; Stack Clamping.

Fuel Cell Diagnostics: Polarization Curve, Current Interrupt, AC Impedance Spectroscopy, Pressure drop as a diagnostic tool.

MODULE V: Fuel Cell System Design and Hydrogen Economy

Fuel Cell System Design: Hydrogen-Oxygen Systems, Hydrogen-Air Systems, Fuel Cell Systems with Fuel Processor, System Efficiency.

Fuel Cells and Hydrogen Economy: Hydrogen Energy Systems, Hydrogen Energy Technologies, Transition to Hydrogen Economy.

Textbooks

1. Ryan P. O'Hayre, Suk-Won Cha, Whitney Colella & Fritz B. Printz, Fuel Cell Fundamentals, John Wiley & Sons, Inc., New Jersey, 2006.
2. Frano Barbir. PEM Fuel Cells: Theory and Practice. Elsevier, 2005

Reference books

1. Vielstich, W, Gasteiger, H. A. Lamm, A. (Eds): Handbook of Fuel Cells Fundamentals, Technology and Applications. John Wiely & Sons Ltd: NY, 2003; Vols1-4
2. Fuel Cell Handbook,7the Edn., EG & G Technical Services, Nov 2004
3. Hordeski, M. F. Alternative Fuels: The Future of Hydrogen, The Fairmont Press: Lilburn, GA, 2007.
4. Kordesch, K.; Simader, G. Fuel Cells and Their Applications. VCH: 1996
5. Larminie, J.; Dicks, A. Fuel Cell Systems Explained. John Wiely & Sons Ltd: Chichester,1999.
6. Andreas Zuttel; Andreas Borgschulte; Louis Schdaptach, Hydrogen as a future energy carrier, Wiley-VCH Verlag GmbH & Co., KGaA, Weinheim, 2008

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours

MODULE 1 (7 hours)		
1.1	Introduction to Fuel Cell, Fuel Cell and conventional processes – comparison.	1
1.2	Types of Fuel Cells.	1
1.3	Application scenarios, Advantages and disadvantages.	1
1.4	Energy & power relations, units.	1
1.5	Working of a PEM fuel Cell.	1
1.6	Major Cell Components and Material Properties of PEMFC.	1
1.7	Processes and Operating Conditions of PEMFC.	1
MODULE II (8 hours)		

2.1	Gibb's free energy-Work potential of fuel, Reversible voltage – NERNST Equation.	1
2.2	Voltage and P, T and concentration dependence – examples.	1
2.3	Faraday's Laws, Efficiency: thermodynamic, voltage and fuel.	1
2.4	Electrochemical reaction fundamentals, electrode kinetics.	1
2.5	Charge transfer and activations energy.	
2.6	Exchange current density - slow and fast reactions, Potential and equilibrium - galvanic potential.	1
2.7	Reaction rate and potential - Butler Volmer equation & Tafel equation.	1
2.8	Exchange Currents and Electrocatalysis.	1
MODULE III (7 hours)		
3.1	Charge transport resistances, voltage losses.	1
3.2	Ionic and electronic conductivities.	1
3.3	Ionic conduction in different FC electrolytes: aqueous, polymeric and ceramic.	1
3.4	Diffusive transport & voltage loss: Limiting current density.	1
3.5	Nernstian and kinetic effect.	1
3.6	Convective transport: flow channels.	1
3.7	gas diffusion/porous layer, gas velocity, pressure.	1
MODULE IV (7 hours)		
4.1	Sizing of a Fuel Cell Stack.	1
4.2	Sizing of a Fuel Cell Stack.	1
4.3	Stack Configuration.	1
4.4	Uniform distribution of Reactants.	1

4.5	Heat removal, Stack Clamping.	1
4.6	Polarization Curve, Current Interrupt.	1
4.7	AC Impedance Spectroscopy, Pressure drop as a diagnostic tool.	1
MODULE V (7 hours)		
5.1	Hydrogen-Oxygen Fuel Cell Systems.	1
5.2	Hydrogen-Air Fuel Cell Systems.	1
5.3	Fuel Cell Systems with Fuel Processor.	1
5.4	System Efficiency.	1
5.5	Hydrogen Energy Systems.	1
5.6	Hydrogen Energy Technologies.	1
5.7	Transition to Hydrogen Economy.	1

CO Assessment Sample Questions	
1	A direct methanol fuel cell uses methanol (CH_3OH) as fuel instead of hydrogen: $CH_3OH + 3/2\ O_2 \rightarrow CO_2 + 2H_2O(liq)$
	Calculate the standard-state reversible potential for a direct methanol fuel cell and standard state Gibbs free energy change of the reaction. Also calculate the reversible voltage of the fuel cell operating at a temperature 350 K. The entropy of the reaction at 350 K is given – 82 J/(mol K). The standard state potential of half reaction is given below: $CO_2 + 6H^+ + 6e \leftrightarrow CH_3OH + H_2O \quad E_0 = +0.03\ V$ $O_2 + 4H^+ + 4e \leftrightarrow 2H_2O \quad E_0 = +1.229\ V$
2	Classify different types of fuel cells.
3	Consider the two fuel cells, Fuel cell-1 (Area 8 cm^2 and resistance 0.15 Ω) and Fuel cell-2 (Area 20 cm^2 and resistance 0.1 Ω). Determine which fuel cell is subjected to larger ohmic voltage loss, at a current density of 3 A/cm^2.

4 Fuel cell is used for power backup having voltage 24 V. Design a hydrogen – air fuel cell stack to produce a power output of 10 kW. Following data are provided:

Parameter	**Unit**	**Value**
Fuel	-	Hydrogen
Oxidant	-	Air
Temperature	K	333
Pressure	kPa	101.3
Gas constant, R	J/(mol K)	8.314
Transfer coefficient, α	-	1
No. of electrons involved, n	-	2
Faraday's constant, F	C/mol	96,485
Current loss, i_{loss}	A/cm^2	0.002
Reference exchange current density, i_0	A/cm^2	3×10^{-6}
Limiting current density, i_L	A/cm^2	1.6
Internal resistance, R_i	Ohm-cm^2	0.15

5 List the unique features that make hydrogen an ideal energy carrier.

24CHE675	HYDROGEN ENERGY TECHNOLOGY	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: This course provides a comprehensive knowledge of hydrogen production, storage and transportation. The course will provide a broad understanding of hydrogen as an energy carrier, the way it will play an important role in various sectors towards decarbonisation. The course also covers the classification and working of fuel cells.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Summarize the importance of hydrogen economy.
CO 2	Explain different methods of hydrogen production.
CO 3	Describe different techniques of hydrogen storage and various safety challenges in hydrogen storage.
CO 4	Describe various methods for hydrogen transportation.
CO 5	Explain the various uses of hydrogen energy.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	3	2				2						1
CO 2	3	2				2						1
CO 3	3	2				2						1
CO 4	3	2				2						1
CO 5	3	2				2						1

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	☐	☐	☐	☐
Understand	☐	☐	☐	☐
Apply	☐	☐	☐	☐
Analyse			☐	
Evaluate			☐	
Create			☐	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	**40**

Total Mark distribution

Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 hours

<u>End Semester Examination [ESE]: Pattern</u>

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I : Introduction to Hydrogen Energy

Hydrogen as an Energy Vector- Global Context and Necessity, Paris CO_2 Emission Reduction Commitment, Hydrogen Economy- Decarbonisation of the Economy, road to the Hydrogen Economy. Properties of hydrogen as fuel. General introduction to infrastructure requirement for hydrogen production, storage, dispensing and utilization, and hydrogen production plants.

MODULE II : Hydrogen Production

Hydrogen production pathways: Thermal process-Steam reformation, Advanced Methods of Steam Reforming, Partial Oxidation Method for

Hydrogen Production. Electrochemical- Electrolysis, photo electro chemical method. Thermo- chemical water splitting. Biological process : hydrogen production from microbial biomass conversion- gasification, pyrolysis.

MODULE III : Hydrogen storage and safety

Underground Hydrogen Storage, compressed storage, Composite cylinders, Glass micro sphere storage, Zeolites, Metal hydride storage, chemical hydride storage and cryogenic storage. Hydrogen safety aspects, backfire, pre-ignition, hydrogen emission NOx control techniques and strategies.

MODULE IV : Transportation of hydrogen

Hydrogen Transportation via Hydrogen Pipelines, Long Distance Hydrogen Transmission, transportation via road, ships and in form of Liquid Organic Hydrogen Carriers (LOHC), hydrogen transported as ammonia, liquefied hydrogen (LH_2) transportation, Hydrogen Refuelling Stations.

MODULE V : Hydrogen usage

Overview of fuel cells, Alkaline fuel cells, Proton exchange membrane fuel cells, Methanol fuel cells, Phosphoric acid fuel cells, Molten carbonate fuel cells, Solid oxide fuel cells, Fuel cell comparison, Hydrogen combustion engines, Hydrogen turbines, Hydrogen gas burner, Gas engine combined heat and power plants.

Text books

1. Gupta, R. B., Hydrogen Fuel: Production, Transport and Storage, CRC Press, Taylor & Francis Group, 2009.
2. Global Hydrogen Review 2021, IEA (2021),Paris, https://www.iea.org/reports/globalhydrogen- review-2021
3. AgataGodula-Jopek, Hydrogen Production by Electrolysis, Wiley-VCH, Germany, 2015
4. Tzimas, E., Filiou, C., Peteves, S.D., &Veyret, J.B. “Hydrogen storage: state-of- the-art and future perspective. Netherlands”: European Communities, 2003.
5. Principles of Fuel Cells by Xianguo Li, Taylor & Francis.

Reference books

1. Michael Hirscher, “Handbook of Hydrogen Storage”, Wiley-VCH, 2010.
2. Electrochemical Methods by A.J. Bard and L.R.Faulkner, John Wiley & Sons, Inc.
3. Fuel Cells: From Fundamentals to Applications by S Srinivasan, Springer.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE 1 (6 hours)		
1.1	Hydrogen as an Energy Vector- Global Context and Necessity, Paris CO_2 Emission Reduction Commitment.	1
1.2	Hydrogen Economy- Decarbonisation of the Economy, road to the Hydrogen Economy.	1
1.3	Properties of hydrogen as fuel.	1
1.4	General introduction to infrastructure requirement for hydrogen production, storage, dispensing and utilization, and hydrogen production plants.	1
1.5	General introduction to infrastructure requirement for hydrogen production, storage, dispensing and utilization, and hydrogen production plants.	1
1.6	General introduction to infrastructure requirement for hydrogen production, storage, dispensing and utilization, and hydrogen production plants.	1
MODULE II (7 hours)		
2.1	Hydrogen production pathways: Thermal process- Steam reformation.	1
2.2	Advanced Methods of Steam Reforming.	1
2.3	Partial Oxidation Method for Hydrogen Production.	1
2.4	Electrochemical- Electrolysis, photo electro chemical method.	1
2.5	Thermo- chemical water splitting.	1
2.6	Biological process : hydrogen production frommicrobial biomass conversion- gasification, pyrolysis.	1
2.7	Biological process : hydrogen production frommicrobial biomass conversion- gasification, pyrolysis.	1
MODULE III (8 hours)		
3.1	Underground Hydrogen Storage, Compressed Storage.	1
3.2	Composite Cylinders, Glass Micro Sphere Storage,	1
3.3	Zeolites, Metal Hydride Storage,	1
3.4	Chemical Hydride Storage	1

3.6	Cryogenic Storage.	1
3.7	Hydrogen Safety Aspects, Backfire, Pre-Ignition,	1
3.8	Hydrogen Emission Nox Control Techniques And Strategies.	1
MODULE IV (6 hours)		
4.1	Hydrogen Transportation via Hydrogen Pipelines,	1
4.2	Long Distance Hydrogen Transmission, transportation via road, ships and in form of Liquid Organic Hydrogen Carriers (LOHC),	1
4.3	Long Distance Hydrogen Transmission, transportation via road, ships and in form of Liquid Organic Hydrogen Carriers (LOHC),	1
4.4	Long Distance Hydrogen Transmission, transportation via road, ships and in form of Liquid Organic Hydrogen Carriers (LOHC),	1
4.5	Hydrogen transported as ammonia, liquefied hydrogen (LH2) transportation, Hydrogen Refuelling Stations.	1
4.6	Hydrogen transported as ammonia, liquefied hydrogen (LH2) transportation, Hydrogen Refuelling Stations.	1
MODULE V (9 hours)		
5.1	Overview of fuel cells, Alkaline fuel cells.	1
5.2	Proton exchange membrane fuel cells.	1
5.3	Methanol fuel cells.	1
5.4	Phosphoric acid fuel cells.	1
5.5	Molten carbonate fuel cells.	1
5.6	Solid oxide fuel cells, Fuel cell comparison.	1
5.7	Hydrogen combustion engines, Hydrogen turbines.	1
5.8	Hydrogen combustion engines, Hydrogen turbines.	1
5.9	Hydrogen gas burner, Gas engine combined heat and power plants.	1

CO Assessment Sample Questions	
1	Explain the importance of hydrogen economy.
2	Differentiate between gasification and pyrolysis.
3	Describe any one hydrogen storage method and mention safety challenges associated with hydrogen storage.
4	“Ammonia can serve as a clean hydrogen energy storage medium”. Justify the statement.
5	List out different types of fuel cells and explain any one in detail.

24CHE685	NANOMATERIALS AND NANOTECHNOLOGY	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: Nanotechnology has emerged as an important and exciting area in science and engineering. It provides promises in many technological advancements with wide range of application fields. The course gives a basic introduction to chemical and physical principles in the synthesis of nanomaterials. It also covers different methods for synthesis, properties, applications and characterization of nanoscale materials.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Explain the concepts of nanotechnology and apply the basic principles of Physics and Chemistry in Nanotechnology.
CO2	Explain synthesis, properties and applications of nanomaterials and nanocomposites.
CO3	Explain the application of nanotechnology in biological fields of drug delivery, biosensors, nanomedicine and therapeutics.
CO4	Explain the various characterization techniques applied to nanomaterials.
CO5	Summarise the applications of nanotechnology in energy sector, catalysis and electronics.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3										2
CO2	3	3										2
CO3	3	3				2						2
CO4	3	3										2
CO5	3	3				2						2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	□	□	□	□
Understand	□	□	□	□
Apply	□	□	□	□
Analyse			□	
Evaluate			□	
Create			□	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	**Attendance**	**Theory [L- T]**			**Total Marks**
		Assignment	**Test-1**	**Test-2**	
3-0-0-0	**5**	**15**	**10**	**10**	**40**

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I : Introduction and general properties

Introduction to Nanotechnology - History of nanotechnology, Pioneers in the field of nanotechnology. Classification of nano-materials: Zero, one, two and three dimensional nanostructured materials. Electromagnetic spectrum, particle size and its significance. Physics of nanomaterials - Size effect on thermal, electrical, electronic, mechanical, optical and magnetic properties of nanomaterials- surface area and aspect ratio- band gap energy- quantum confinement effect. Chemistry of nanomaterials - Ionic properties of nanomaterials, electronic phenomenon in nanostructures.

MODULE II : Synthesis methods

Synthesis methods - top down and bottom up approaches. Top down approach – size reduction techniques like milling and machining. Bottom up approach - Sol-gel methods, Chemical vapour deposition, Physical Vapour Deposition, Wet chemical synthesis, Laser ablation methods. Synthesis, properties and applications of nanomaterials like gold, silver and different types of nano oxides like Al2O3, TiO2, ZnO and SiO_2.

MODULE III: Nanocomposites and Bio nanotechnology

Nanocomposites - Matrix materials- Basics of Metal matrix, Ceramic Matrix and Polymer Matrix nanocomposites - Nano-reinforcements, nanofillers-nanoclays. Introduction to Bio nanotechnology (fundamental concepts only) - Nanomedicine,Drug delivery, Therapeutic applications. Applications of biosensors.

MODULE IV: Characterization techniques

Characterisation techniques - Scanning Electron Microscopy (SEM) - Energy Dispersive X-ray Spectroscopy (EDS) - Transmission Electron Microscopy (TEM) - Atomic Force Microscopy (AFM), UV-visible spectroscopy, Raman spectroscopy, Nuclear Magnetic Resonance Spectroscopy (NMR), Fourier Transform Infrared Spectroscopy (FTIR) X-Ray Diffraction (XRD), Dynamic Light Scattering (DLS), Thermogravimetric analysis (TGA).

MODULE V : Applications in energy, catalysis and electronics

Applications (fundamental concepts only) -: Nanoscale advances in energy and catalysis - Nanotechnology for sustainable energy, nanotechnology enabled renewable energy technologies. Application of nanomaterials in catalysis. Nanoelectronics - Introduction to Micro Electro Mechanical Systems (MEMS), Nano Electro Mechanical Systems (NEMS).

Text books

1. Joel I. Gersten, ―The Physics and Chemistry of Materials, Wiley, 2001
2. G. Cao, Nanostructures & Nanomaterials: Synthesis, Properties & Applications, Imperial College Press, 2004. 2. S Zhang, L. Li and Ashok Kumar, Materials Characterization Techniques, CRC Press (2008).
3. T. Pradeep, Nano: The Essentials, McGraw-Hill (India) Pvt Limited, 2008.
4. Nanocomposite science and technology, Pulikel M. Ajayan, Wiley-VCH 2005
5. C. M. Niemeyer, C. A. Mirkin, ―Nanobiotechnology: Concepts, Applications
   and Perspectives, Wiley – VCH, (2004)
6. J. Twidell and T. Weir, Renewable Energy Resources, E & F N Spon Ltd, London, (1986).
7. Nanotechnology in Catalysis Volumes 1 and 2, Bing Zhou, Sophie Hermans, Gabor A. Somorjai , Springer Science & Business Media, 05-Sep-2007.
8. W.R.Fahrner, Nanotechnology and Nanoelectronics–Materials,

Devices, Measurement Techniques, Springer-Verlag Berlin, Germany (2006).

Reference books

1. K.W. Kolasinski, ―Surface Science: Foundations of Catalysis and Nanoscience, Wiley, 2002.
2. S. Edelstein and R. C. Cammarata, ―Nanomaterials: Synthesis, Propertiesand Applications, Institute of Physics Pub., 1998.
3. S.Yang and P.Shen: ―Physics and Chemistry of Nanostructured Materials, Taylor & Francis, 2000.
4. Z L Wang (Ed.), Characterization of Nanophase materials, Willet-VCH (2000).
5. Guo, Jinghua (Ed.), X-rays in Nanoscience -Spectroscopy, Spectromicroscopy, and Scattering Techniques, John Wiley &Sons (2010).
6. Handbook of Nanoscience, Engineering and Technology, Kluwer publishers, 2002.
7. David S Goodsell, "Bionanotechnology, John Wiley & Sons, (2004).
8. Zheng Cui, Nanofabrication, Principles, Capabilities and Limits, Springer Science + business media, New York (2008).

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE 1 (7 hours)		
1.1	Introduction to Nanotechnology - History of nanotechnology.	1
1.2	Pioneers in the field of nanotechnology.	1
1.3	Classification of nano-materials: Zero, one, two and three dimensional nano-structured materials.	1
1.4	Electromagnetic spectrum, particle size and its significance.	1
1.5	Physics of nanomaterials - Size effect on thermal, electrical, electronic and mechanical properties.	1
1.6	Optical and magnetic properties of nanomaterials- surface area and aspect ratio- band gap energy quantum confinement size effect.	1
1.7	Chemistry of nanomaterials - Ionic properties of nanomaterials, electronic phenomenon in nanostructures.	1
MODULE II (7 hours)		

2.1	Top down approach – size reduction techniques like milling and machining.	1
2.2	Bottom up approach - Sol-gel methods, Chemical vapour deposition.	1
2.3	Physical Vapour Deposition, Wet chemical synthesis, Laser ablation methods.	1
2.4	Physical Vapour Deposition, Wet chemical synthesis, Laser ablation methods.	1
2.5	Synthesis, properties and applications of nanomaterials like gold, silver.	1
2.6	Synthesis, properties and applications of different types of nano-oxides like Al2O3, TiO2, ZnO and SiO2.	1
2.7	Synthesis, properties and applications of different types of nano-oxides like Al2O3, TiO2, ZnO and SiO2.	1
MODULE III (7hours)		
3.1	Matrix materials- Basics of Metal matrix.	1
3.2	Ceramic Matrix nanocomposites.	1
3.3	Polymer Matrix nanocomposites - Nano-reinforcements,	1
3.4	Nanofillers- nanoclays.	1
3.5	Introduction to bionanotechnology- Nanomedicine.	1
3.6	Drug delivery, Therapeutic applications.	1
3.7	Applications of biosensors.	1
MODULE IV (7hours)		
4.1	Scanning Electron Microscopy (SEM) - Energy Dispersive X- ray Spectroscopy (EDS).	1
4.2	Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM).	1
4.3	UV-visible spectroscopy, Raman spectroscopy.	1

4.4	Nuclear Magnetic Resonance Spectroscopy (NMR)	1
4.5	Fourier Transform Infrared Spectroscopy (FTIR).	1
4.6	X-Ray Diffraction (XRD), Dynamic Light Scattering (DLS)	1
4.7	Thermogravimetric analysis (TGA).	1
MODULE V (8 hours)		
5.1	Applications: Nanotechnology for sustainable energy.	1
5.2	Nanotechnology enabled renewable energy technologies.	1
5.3	Application of nanomaterials in catalysis.	1

5.4	Application of nanomaterials in catalysis.	1
5.5	Nanotechnology enabled renewable energy technologies.	1
5.6	Nanotechnology enabled renewable energy technologies.	1
5.7	Nanoelectronics - Introduction to Micro Electro Mechanical Systems (MEMS)	1
5.8	Nano Electro Mechanical Systems (NEMS).	1

CO Assessment Sample Questions	
1	Write a note on pioneers who contributed for the propagation of the ideas of nanotechnology.
2	Distinguish between top down and bottom up approach in nanomaterial synthesis.
3	Explain the application of nanotechnology in drug delivery.
4	Compare and contrast SEM and TEM.
5	Describe Nano Electro Mechanical Systems and their applications.

24CHI695	FERMENTATION TECHNOLOGY	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: This course aims to bring a basic knowledge of the various processes in fermentation for the development of biologically relevant products. This includes microbial growth kinetics, medias for fermentation, product development and recovery, and fermentative productive technology.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Explain the process of fermentation, design of fermenter and factors affecting fermentation process.
CO 2	Analyze microbial growth kinetics, comparison of batch and continuous culture processes and preservation of industrially important microorganism.
CO 3	Formulate media for industrial fermentation.
CO 4	Explain the product development, product recovery and various purification strategy for fermentative products.
CO 5	Describe the basics of Industrial production of primary metabolites and secondary metabolites and packing and labelling through good manufacturing practices.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	3	2										2
CO 2	3	2										2
CO 3	3	2										2
CO 4	3	2										2
CO 5	3	2										2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other Tools	
Remember	✓	✓	✓	✓
Understand	✓	✓	✓	✓
Apply	✓	✓	✓	✓
Analyse			✓	
Evaluate			✓	
Create			✓	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 hours

End Semester Examination [ESE]: Pattern			
PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks)	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Introduction to fermentation

Introduction to fermentation-Design of fermenter-body construction-aeration system agitation system-baffles- sensors. Type of fermenters-Waldhof, Tower, Deep jet, Cyclone column, packed tower and airlift fermenter Different types of fermentation process-batch, continuous, fed batch. Factors affecting fermentation process- physical, chemical and biological factors.

MODULE II: Microbial Growth Kinetics

Microbial Growth Kinetics: Batch culture-continuous culture-fed batch system- biomass productivity-metabolite productivity-continuous brewing-comparison of batch and continuous culture. Isolation and preservation of industrially important microorganisms. Preservation of industrially important microorganisms.MODULE III: Media for industrial fermentation Media for industrial fermentation- introduction-typical media-medium formulation-water energy sources-carbon sources-factors affecting the selection of carbon source carbohydrates, oils and fats, nitrogen source, minerals, growth factors, chelators, buffers, antifoam agents, pH. Medium optimization-animal cell media - serum free media, protein free media. Non-nutritional media supplement**.**

MODULE IV: Product development and product recovery

Product development and product recovery-cell. Introduction to purification of fermentative products-removal of microbial cells and other solid matters. Cell disruption physical-mechanical-chemical-enzymatic methods. Product recovery- chromatography adsorption-ion-exchange-HPLC. Filtration- types of filters-batch- continuous filters centrifugation. Liquid/liquid extraction and dialysis.

MODULE V: Introduction to fermentative production technology

Introduction to fermentative production technology: Industrial production of Primary metabolites and secondary metabolites. Introduction to enzyme production- Intracellular and Extracellular Enzymes- Production of Proteases. Fermentative production of ethanol, acetone- butanol, Organic acids- citric acid. Amino acids- lysine and phenylalanine, Vitamins riboflavin and ascorbic acid. Antibiotics- penicillin SCP production. Packing and labelling. Good Manufacturing Practices, Biosafety- laws and concerns at different levels- individual, institution and society.
Forms of IPR and process of patenting.

Text books

1. Peter F. Stanbury Allan Whitaker Stephen Hall, Principles of Fermentation Technology,2nd Edition, Butterworth-Heinemann 1995.
2. Michael L Shuler, Fikret Kargi, Bioprocess Engineering Basic Concepts, Prentice Hall, 1992.
3. WulfCruger and AnnelieseCrueger, Biotechnology: A Textbook of Industrial Microbiology, 2nd Edition, Panima Publishing Corporation, 2004.

Reference books

1. Michael C Flickinge (Ed.), Upstream Industrial Biotechnology, Volumes 1 & 2, Wiley 2013.
2. Brian McNeil, Linda Harvey (Eds.), Practical Fermentation Technology, Wiley, 2008.
3. J E Bailey, D F Ollis, Biochemical Engineering Fundamentals, 2/e, McGraw-Hill Chemical Engineering Series, 1986.
4. BioprocessTechnology, P.T. Kalichelvan and Arul Pandi, 2009, MJP Publishers, Chennai.
5. Bioprocess Technology- Kinetics and reactors, Antan Moser and Philip Manor,.1998, Springer.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1 (8 hours)	
1.1	Design of fermenter.	1
1.2	Body construction-aeration system.	1
1.3	Baffles- sensors.	1
1.4	Type of fermenters- Waldhof, Tower, Deep jet, Cyclone column,	1
1.5	Packed tower and airlift fermenter.	1
1.6	Different types of fermentation process-batch,	1
1.7	Continuous, fed batch.	1
1.8	Factors affecting fermentation process- physical, chemical and biological factors.	1
	MODULE II (7 hours)	
2.1	Batch culture-continuous culture.	1
2.2	Fed batch system.	1
2.3	Biomass productivity, metabolite productivity.	1
2.4	Continuous brewing.	1

2.5	Comparison of batch and continuous culture.	1
2.6	Isolation of industrially important microorganisms.	1
2.7	Preservation of industrially important microorganisms.	1
MODULE III (6 hours)		
3.1	Introduction -typical media-medium formulation-water. -	1
3.2	Energy sources-carbon sources-factors affecting the selection of carbon source.	1
3.3	Carbohydrates, oils and fats, nitrogen source, minerals, growth factors, chelators, buffers, antifoam agents, pH.	1
3.4	Medium optimization-animal cell media.	1
3.5	Serum free media-protein free media.	1
3.6	Non-nutritional media supplement.	1
MODULE IV (9 hours)		
4.1	Introduction to purification of fermentative products.	1
4.2	Removal of microbial cells and other solid matters.	1
4.3	Cell disruption-physical-mechanical methods.	1
4.4	Cell disruption-chemical-enzymatic methods.	1
4.5	Product recovery.	1
4.6	Chromatography.	1
4.7	Adsorption-ion-exchange HPLC.	1
4.8	Filtration- types of filters-batch-continuous filters centrifugation.	1
4.9	Liquid/liquid extraction and dialysis.	1
MODULE V (10 hours)		

5.1	Industrial production of Primary metabolites and secondary metabolites.	1
5.2	Introduction to enzyme production – Intracellular and Extracellular Enzymes- Production of Proteases.	1
5.3	Fermentative production of ethanol.	1
5.4	Acetone-Butanol.	1
5.5	Organic acids- citric acid.	1
5.6	Amino acids- lysine and phenylalanine, Vitamins- riboflavin and ascorbic acid.	1
5.7	Antibiotics-penicillin SCP production.	1
5.8	Packing and labelling. Good Manufacturing Practices.	1
5.9	Biosafety laws and concerns at different levels- individual, institution and society.	1
5.10	Forms of IPR and process of patenting.	1

CO Assessment Sample Questions	
1	Illustrate the working of an airlift fermenter.
2	Draw a microbial growth curve and explain the different phases.
3	Brief about the factors to be considered during the selection of carbon and nitrogen sources in the media.
4	Discuss about the methods for the removal of cells and solid matters.
5	With a neat sketch outline the production of any one intracellular enzyme.

SIXTH SEMESTER HONOUR

24CHH609	ADVANCED FLUID MECHANICS	L	T	P	J	S	C	Year of Introduction
		4	0	0	0	4	4	2024

Preamble: The main objective of the course is to undertake a sustained learning in fluid mechanics to advance their knowledge in this field. This course covers fundamental flow characteristics, fluid flow theorems, flow past different bodies, different types of flow boundary conditions and concept of boundary layer theory. This course enhances the understanding of fluid mechanics, including the equations of motion in differential form.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Explain the different flow characteristics and flow functions.
CO2	Explain the different flow trajectory tracking approaches and flow governing equations.
CO3	Analyse the behavior of flow past different bodies.
CO4	Explain the significance of Navier stokes equation and apply the concepts of Hagen Poissuille and couette flow.
CO5	Apply the concepts of momentum boundary layer in different engineering applications.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	3	3										
CO 2	3	3										
CO 3	3	3	2									
CO 4	3	3	2									
CO 5	3	3	2									

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	✔
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
4-0-0-0	5	5	10	10	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	

End Semester Examination [ESE]: Pattern			
PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS
MODULE I: Fluid flow functions (9 hours)
Basic Concepts and Fundamentals: Fluid statics, Cartesian Tensors, Fluid Kinematics, and Description of fluid motion –Types of motion of fluid elements, Vorticity and circulation – Concept of rotational and irrotational flows. Equation of motion of forced and free vortex flow. Stream function and Potential function. Stream function and its relation with velocity field. Relation between stream function and stream lines - Relation between stream function and velocity potential for a 2-D irrotational and incompressible flow.
MODULE II: Flow tracking approaches and equations (9 hours)
Relation between stream lines and lines of constant potential. Sketching of stream lines. Lagrangian and Eulerian approaches, acceleration, temporal acceleration, convective acceleration. Reynolds transport theorem, derivation of continuity and momentum equations using Reynolds transport theorem. Problems on the application

of momentum equation

MODULE III: Characteristics of flow past immersed bodies (10 hours)

Potential flow: Uniform flow, source flow, sink flow, free vortex flow and super imposed flow-source and sink pair, doublet, plane source in a uniform flow (flow past a half body), source and sink pair in a uniform flow (flow past a Rankine oval body), doublet in a uniform flow (flow past a circular cylinder). Pressure distribution on the surface of the cylinder. Flow past a cylinder with circulation, Kutta- Juokowsky's law. Complex flow potential, complex flow potentials for source, sink, vortex and doublet.
Potential flow between two parallel plates, potential flow in a sector.

MODULE IV: Different types of flow governing equations (10 hours)

Incompressible viscous flow. Concepts of laminar and turbulent flows. Stokes viscosity law. Navier Stoke's equation and significance (Derivation not necessary). Simplification of Navier stock equation for steady incompressible flows with negligible body forces. Parallel flow through straight channel and couette flow. Hagen - Poiseuille flow. Derivation of Hagen Poissuille equations for velocity and discharge through a pipe, derivation of friction factor for laminar flow, Couette flow for negative, zero and positive pressure gradients, flow in a rotating annulus, Viscometer based on rotating annulus.

MODULE V: Concepts of boundary layer (10 hours)

Boundary layer theory, Boundary layer thickness, Displacement thickness, momentum thickness, Energy thickness and their calculation. Laminar Boundary Layers, Boundary layer equations; Boundary layer on a flat plate, Prandtl boundary layer equations, Blasius solution for flow over a flat plate, Von- Karman momentum integral equations, Pohlhausen approximation solution of boundary layer for non-zero pressure gradient flow.

Text books

1. Bansal R. K., A Text Book of Fluid Mechanics and Machines, Laxmi Publications, 2010.
2. 2. Douglas J. F., Fluid Mechanics, Pearson Education, 2005.
3. 3. Kumar D. S., Fluid Mechanics and Fluid Power Engineering, S. K. Kataria & Sons, 1987.
4. 4. Muralidhar K., G. Biswas, Advanced Engineering Fluid Mechanics, Alpha Science
5. International limited, 2005.
6. 5. Rama D. D., Fluid Mechanics and Machines, New Age International,

2009.

Reference books

1. Schlichting H., K. Gersten , Boundary Layer Theory, 8/e, Springer 2000.
2. Shames I. H., Mechanics of Fluids, 4/e, McGraw-Hill, 2002.
3. Streeter V. L. and E. B. Wylie, Fluid Mechanics, McGraw-Hill, 1979.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE 1		
1.1	Fluid statics, Cartesian Tensors, Fluid Kinematics, and Description of fluid motion	1
1.2	Types of motion of fluid elements, Vorticity and circulation	1
1.3	Concept of rotational and irrotational flows. Equation of motion of forced and free vortex flow.	1
1.4	Stream function and Potential function. Stream function and its relation with velocity field.	1
1.5	Stream function and Potential function. Stream function and its relation with velocity field.	1
1.6	Relation between stream function and stream lines	1
1.7	Relation between stream function and stream lines	1
1.8	Relation between stream function and velocity potential for a 2-D irrotational and incompressible flow.	1
1.9	Relation between stream function and velocity potential for a 2-D irrotational and incompressible flow.	1
MODULE II		

2.1	Relation between stream lines and lines of constant potential.	1
2.2	Sketching of stream lines.	1
2.3	Lagrangian and Eulerian approaches	1
2.4	acceleration, temporal acceleration, convective acceleration.	1
2.5	acceleration, temporal acceleration, convective acceleration.	1
2.6	Reynolds transport theorem, derivation of continuity and momentum equations using Reynolds transport theorem.	1
2.7	Reynolds transport theorem, derivation of continuity and momentum equations using Reynolds transport theorem.	1
2.8	Problems on the application of momentum equation.	1
2.9	Problems on the application of momentum equation.	1
MODULE III		
3.1	Uniform flow, source flow, sink flow, free vortex flow and super imposed flow	1
3.2	flow-source and sink pair, doublet, plane source in a uniform flow (flow past a half body),	1
3.3	source and sink pair in a uniform flow (flow past a Rankine oval body), doublet in a uniform flow (flow past a circular cylinder).	1
3.4	source and sink pair in a uniform flow (flow past a Rankine oval body), doublet in a uniform flow (flow past a circular cylinder).	1
3.5	Pressure distribution on the surface of the cylinder. Flow past a cylinder with circulation	1
3.6	Pressure distribution on the surface of the cylinder. Flow past a cylinder with circulation.	1
3.7	Kutta- Juokowsky's law	
3.8	Complex flow potential, complex flow potentials for source, sink, vortex and doublet.	1
3.9	Potential flow between two parallel plates, potential flow in a sector.	1
3.10	Potential flow between two parallel plates, potential flow in a sector.	1
MODULE IV		
4.1	Incompressible viscous flow.	1

4.2	Concepts of laminar and turbulent flows.	1
4.3	Stokes viscosity law. Navier Stoke's equation and significance	1
4.4	Simplification of Navier stock equation for steady incompressible flows with negligible body forces.	1
4.5	Parallel flow through straight channel and couette flow. Hagen - Poiseuille flow.	1
4.6	Derivation of Hagen Poissuille equations for velocity and discharge through a pipe,	1
4.7	Derivation of friction factor for laminar flow, Couette flow for negative, zero and positive pressure gradients	1
4.8	Derivation of friction factor for laminar flow, Couette flow for negative, zero and positive pressure gradients	1
4.9	Flow in a rotating annulus, Viscometer based on rotating annulus.	1
4.10	Flow in a rotating annulus, Viscometer based on rotating annulus.	1
	MODULE V	
5.1	Boundary layer theory and Boundary layer thickness	1
5.2	Displacement thickness and momentum thickness	1
5.3	Energy thickness and its calculatin	1
5.4	Laminar Boundary Layers, Boundary layer equations; Boundary layer on a flat plate	1
5.5	Laminar Boundary Layers, Boundary layer equations; Boundary layer on a flat plate	1
5.6	Prandtl boundary layer equations, Blasius solution for flow over a flat plate,	1
5.7	Prandtl boundary layer equations, Blasius solution for flow over a flat plate,	1
5.8	Von- Karman momentum integral equations	1
5.9	Pohlhausen approximation solution of boundary layer for non-zero pressure gradient flow,	1
5.10	Pohlhausen approximation solution of boundary layer for non-zero pressure gradient flow	1

CO Assessment Questions

1	The velocity potential function (Φ) is given by an expression $$\Phi = -\frac{xy^3}{3} - x^2 + \frac{x^3 y}{3} + y^2$$ (i) Find the velocity components in x and y direction. (ii) Show that Φ represents a possible case of flow.
2	Derive the momentum equation using Reynolds transport theorem.
3	A uniform flow of 12 m/s is flowing over a doublet (circular cylinder) of strength 18 m^2/s. The doublet is in the line of the uniform flow. Determine (i) Shape of the Rankine oval (ii) Radius of the Rankine cycle (iii) Value of stream line function at Rankine cycle (iv) Resultant velocity at a point on the Rankine circle at an angle of 30^0 from x-axis
4	The blood flow through a large artery of radius 2.5 mm is found to be 20 cm long. The pressure across the artery ends is 380 Pa, calculate the blood's average speed.
5	Find the displacement thickness, the momentum thickness and energy thickness for the velocity distribution in the boundary layer given by $$\frac{u}{U} = 2\frac{y}{\delta} - \left(\frac{y}{\delta}\right)^2$$

24CHH610	ENERGY CONSERVATION AND WASTE HEAT RECOVERY	L	T	P	J	S	C	Year of Introduction
		4	0	0	0	4	4	2024

Preamble: The proposed course introduces various methods of waste heat recovery that have been employed by the industry to harness the energy stored in waste heat and use it for generation of additional electric power. The course gives a detailed idea about the involvement of thermodynamic principles in waste heat recovery systems, heat exchanger networks and direct energy production methods and its storage. This course helps to build the students fundamental knowledge in different waste heat recovery processes and energy storage mechanisms.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Describe the thermodynamics aspects of waste heat recovery
CO 2	Describe the thermodynamic cycles involved in the waste heat recovery process.
CO 3	Describe the heat exchanger networks for waste heat recovery.
CO 4	Explain the direct conversion technologies for energy production.
CO 5	Describe the commonly used energy storage techniques.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	3	3	2									
CO 2	3	3	2									
CO 3	3	3	2									
CO 4	3	3	2									
CO 5	3	3	2									

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
4-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Thermodynamics aspects of waste heat recovery (9 hrs)

Introduction to Waste Heat, Importance of Waste Heat Recovery, Thermodynamic principles of waste heat recovery– Introduction to First and Second Laws, reversible cycles, Entropy, Entropy Generation, Exergy, First and Second Law efficiency

MODULE II: Thermodynamic cycles (9 hrs)

Power Plant Cycles -Rankine Cycle, modification of Rankine cycle, examples. Gas Turbine Cycle, Combined Cycle, Combined Gas Turbine-Steam Turbine Power Plant, Heat Recovery Steam Generators, Thermodynamic cycles for low temperature application, Cogenerations.

MODULE III: Waste heat recovery using heat exchanger (10 hrs)

Introduction to Heat Exchangers, Analysis – LMTD and ε-NTU method Analysis of Heat Exchanger, Special Heat Exchangers for Waste Heat Recovery (run around coil type), Synthesis of Heat Exchanger network, corrigendum design of heat exchanger network, Heat pipes & Vapor Chambers.

MODULE IV: Direct conversion technologies (10 hrs)

Introduction to Thermo electric generation, Seebeck and Peltier effect, Thermoelectric
Generators-Functioning and applications, performance and optimisation, Direct Thermo-ionic conversion, Thermo photo voltaic generation, Magneto hydro Dynamics, Heat Pump; Heat Recovery from Incinerators

MODULE V: Energy storage (10 hrs)

Energy Storage – Introduction to Energy Storage systems, Energy Storage systems
techniques – Pumped hydro, Compressed Air, Flywheel, Superconducting Magnetic energy storages, Thermal storage (Sensible & Latent)- pressurised water storage and solar power, Electro-chemical Energy Storage - Battery and Fuel cells-PFMC fuel cell.

Text books

1. J. H. Harlock, Combined Heat and Power, Pergaman Press, 1987
2. F. Kreith and R. E. West, Energy Efficiency, CRC handbook, CRC Press,1999
3. Kays and London, Compact Heat Exchangers, 3rd edition, McGraw-Hill, New York.

Reference books

1. Prof. P.K. Das and A. Bhattacharya, Energy Conservation and Waste Heat Recovery, NPTEL course, IIT Kharagpur

No.		No. of Hours
	MODULE 1	
1.1	Introduction to Waste Heat, Importance of Waste Heat Recovery	1
1.2	Introduction to Waste Heat, Importance of Waste Heat Recovery	1
1.3	Thermodynamic principles of waste heat recovery– Introduction to First and Second Laws flows.	1
1.4	Thermodynamic principles of waste heat recovery– Introduction to First and Second Laws flows.	1
1.5	Reversible cycles	1
1.6	Entropy, Entropy Generation	1
1.7	Entropy, Entropy Generation	1
1.8	Exergy, First and Second Law efficiency	1

1.9	Exergy, First and Second Law efficiency	1
MODULE II		
2.1	Rankine Cycle, modification of Rankine cycle, examples.	1
2.2	Rankine Cycle, modification of Rankine cycle, examples	1
2.3	Gas Turbine Cycle	1
2.4	Combined Cycle	1
2.5	Combined Gas Turbine-Steam Turbine Power Plant	1
2.6	Heat Recovery Steam Generators	1
2.7	Thermodynamic cycles for low temperature application	1
2.8	Thermodynamic cycles for low temperature application	1
2.9	Cogenerations.	1
MODULE III		
3.1	Introduction to Heat Exchangers	1
3.2	LMTD and ε-NTU method Analysis of Heat Exchanger	1
3.3	LMTD and ε-NTU method Analysis of Heat Exchanger	1
3.4	Special Heat Exchangers for Waste Heat Recovery	1
3.5	Special Heat Exchangers for Waste Heat Recovery	1
3.6	Synthesis of Heat Exchanger network	1
3.7	Synthesis of Heat Exchanger network,	1
3.8	Corrigendum design of heat exchanger network	1
3.9	Corrigendum design of heat exchanger network	1
3.10	Heat pipes & Vapor Chambers.	1
MODULE IV		
4.1	Introduction to Thermo electric generation	1
4.2	Seebeck and Peltier effect	1
4.3	Thermoelectric Generators-Functioning and applications	1

4.4	Thermoelectric Generators-Functioning and applications	1
4.5	Performance and optimisation	1
4.6	Performance and optimisation	1
4.7	Thermo photovoltaic generation,	1
4.8	Magneto hydro Dynamics	1
4.9	Heat Pump	1
4.10	Heat Recovery from Incinerators	1
MODULE V		
5.1	Introduction to Energy Storage systems	1
5.2	Pumped hydro, Compressed Air	1
5.3	Pumped hydro, Compressed Air	1
5.4	Flywheel, Superconducting Magnetic energy storages	1
5.5	Flywheel, Superconducting Magnetic energy storages	1
5.6	Pressurized water storage and solar power	1
5.7	Pressurized water storage and solar power	1
5.8	Introduction to Electro-chemical Energy Storage	1
5.9	Battery and Fuel cells-PFMC fuel cell.	1
5.10	Battery and Fuel cells-PFMC fuel cell.	1

CO assessment sample questions	
1	Describe the importance of heat pump and heat engine in the waste heat recovery process.
2	With a flow chart explain the working of combined gas and steam power plant and list out the advantages.

3	Describe significance and working of run around coil type heat exchanger.
4	Describe the construction and working of magneto hydro dynamics power generation method.
5	Explain the electrochemical energy storage techniques.

24CHH611	MODERN CONTROL THEORY	L	T	P	J	S	C	Year of Introduction
		4	0	0	0	4	4	2024

Preamble: This course aims to cultivate proficiency in the depiction of systems and the formulation of their transfer function models. It endeavors to impart comprehensive understanding of the time response characteristics of systems and the analysis of steady-state errors. Additionally, the course seeks to instill fundamental knowledge in deriving open-loop and closed-loop frequency responses of systems. A key objective is to foster comprehension of control system stability concepts and the various methods employed for stability analysis.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Solve numerical problems on state space theorem
CO2	Develop a transfer function from a state model.
CO3	Develop solutions of state equations.
CO4	Define stability and find stability analysis using the Liapunov theorem.
CO5	Find stability of nonlinear systems using the Krasovski method and variable gradient method.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3								
CO2	3	3	3	3								
CO3	3	3	3	3								
CO4	3	3	3	3								
CO5	3	3	3	3								

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
4-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 Hrs

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: State Variable Analysis and Design (12 Hours)

Introduction, concept of state, state variables and state model, state modeling of linear systems, linearization of state equations. State space representation using physical variables, phase variables & canonical variables.

MODULE II: Derivation of transfer function from state model (8 Hours)

Derivation of transfer function from state model, diagonalization, Eigen values, Eigen vectors, generalized Eigenvectors.
Evaluation of Matrix polynomial, inverse of a matrix, state transition matrix. Quadratic forms and sign definiteness of quadratic forms State space analysis of control systems.

MODULE III: Solution of state equation (10 Hours)

Solution of state equation, state transition matrix and its properties, computation using Laplace transformation, power series method, Cayley-Hamilton method, concept of controllability & observability, methods of determining controllability & observability.

MODULE IV: Non-linear systems (9 Hours)

Introduction, behavior of a non-linear system, common physical nonlinearity saturation, friction, backlash, dead zone, relay, multivariable non-linearity.

Phase plane method, singular points, stability of nonlinear system, limit cycles, construction of phase trajectories

MODULE V: Lyapunov stability criteria (9 Hours)

Lyapunov stability criteria, Lyapunov functions, direct method of Lyapunov & the linear system, Hurwitz criterion & Lyapunov's direct method, construction of Lyapunov functions for nonlinear system by Krasvskii's method.

Textbooks

1. Katsuhiko Ogata, Modern control engineering, Prentice- Hall of India, Fifth edition 2015.
2. Chen.C.F and I.J Haas, Elements of control system analysis, Prentice Hall First edition 1968

Reference books

1. I.J. Nagarath & M. Gopal, "Control System Engineering", 5th edition, New Age International Ltd.
2. Katsuhiko Ogata, State space analysis of control systems, Prentice Hall, First edition 1967
3. Kuo.B.C, Analysis and synthesis of sampled data control systems, Prentice Hall, First edition 1963
4. A. Nagoor Kani, Advanced Control Theory, RBA Publications. Second edition 1999

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1	
1.1	Introduction, the concept of state, state variables, and state model	1
1.2	Introduction, the concept of state, state variables, and state model	1
1.3	state modeling of linear systems	1
1.4	state modeling of linear systems	1
1.5	linearization of state equations	1
1.6	linearization of state equations	1
1.7	State space representation using physical variables	1
1.8	State space representation using physical variables	1
1.9	State space representation using phase variables	1
1.10	State space representation using phase variables	1
1.11	State space representation using canonical variables.	1
1.12	State space representation using canonical variables.	1
	MODULE II	
2.1	Derivation of transfer function from state model	1
2.2	Derivation of transfer function from state model	1

2.3	diagonalization	1
2.4	Eigenvalues, Eigen vectors	1
2.5	generalized Eigenvectors.	1
2.6	Evaluation of Matrix polynomial, inverse of a matrix, state transition matrix.	1
2.7	Quadratic forms and sign definiteness of quadratic forms State space analysis of control systems.	1
2.8	Quadratic forms and sign definiteness of quadratic forms State space analysis of control systems.	1
	MODULE III	
3.1	Solution of state equation	1
3.2	state transition matrix and its properties	1
3.3	computation using Laplace transformation	1
3.4	computation using the power series method	1
3.5	computation using the Cayley-Hamilton method	1
3.6	computation using the Cayley-Hamilton method	1
3.7	concept of controllability & observability	1
3.8	concept of controllability & observability	1
3.9	methods of determining controllability & observability	1
3.10	methods of determining controllability & observability	1
	MODULE IV	
4.1	Introduction, the behavior of a non-linear system	1
4.2	common physical nonlinearity saturation, friction, backlash, dead zone, relay, multivariable non-linearity.	1
4.3	common physical nonlinearity saturation, friction, backlash, dead zone, relay, multivariable non-linearity.	1
4.4	common physical nonlinearity saturation, friction, backlash, dead zone, relay, multivariable non-linearity.	1
4.5	Phase plane method, singular points, stability of nonlinear system, limit cycles, construction of phase trajectories	1
4.6	Phase plane method, singular points, stability of nonlinear system, limit cycles, construction of phase trajectories	1
4.7	Phase plane method, singular points, stability of nonlinear system, limit cycles, construction of phase trajectories	1

4.8	Phase plane method, singular points, stability of nonlinear system, limit cycles, construction of phase trajectories	1
4.9	Phase plane method, singular points, stability of nonlinear system, limit cycles, construction of phase trajectories	1
	MODULE V	
5.1	Lyapunov stability criteria	1

5.2	Lyapunov functions	1
5.3	The direct method of Lyapunov & the linear system	1
5.4	Hurwitz criterion & Lyapunov's direct method,	1
5.5	Hurwitz criterion & Lyapunov's direct method,	1
5.6	Hurwitz criterion & Lyapunov's direct method,	1
5.7	Hurwitz criterion & Lyapunov's direct method,	1
5.8	construction of Lyapunov functions for nonlinear systems by Krasvskii's method.	1
5.9	construction of Lyapunov functions for nonlinear systems by Krasvskii's method.	1

CO Assessment Sample Questions	
1	Explain the basic elements of a state diagram. Draw the block diagram of the system described by the state model, $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} a_1 & a_2 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} u; y = x_3$
2	Explain Quadratic forms and sign definiteness of Quadratic forms.
3	A discrete-time system has a state equation given by: $x(k + 1) = [-\ 6\ 2\ \ -\ 6\ 1\ ]x(k)$ Use the Cayley Hamilton approach to find out the state transition matrix.
4	Use the variable gradient method to investigate the stability of the equilibrium state of a nonlinear system described by the equations $\dot{x}_1 = - x_1 + 2 x_1^2 x_2$

	$\dot{x}_2 = -x_2$
5	Consider the nonlinear system $\dot{x}_1 = -x_1 - x_2^2$ $\dot{x}_2 = -x_2$ Find a region of asymptotic stability using Krasovski method.

SIXTH SEMESTER
MINOR

24CHM609	CHEMICAL REACTION ENGINEERING	L	T	P	J	S	C	Year of Introduction
		4	0	0	0	4	4	2024

Preamble: The course is designed to provide students with a comprehensive understanding of the fundamental principles and practical aspects governing chemical reactions in engineering processes. This course aims to equip students with the knowledge and skills necessary to analyze, design, and optimize chemical processes.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Explain the principles of chemical kinetics.
CO2	Distinguish between elementary and no-elementary reactions.
CO3	Determine chemical kinetic parameters using batch reactor data.
CO4	Develop design equations of ideal reactors.
CO5	Describe non ideal behavior of chemical reactors.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2										1
CO2	2	2										1
CO3	3	2										1
CO4	3	2										1
CO5	3	2										1

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	

4-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 Hours

End Semester Examination [ESE]: Pattern			
PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS
MODULE I: Introduction
Scope of Chemical Reaction Engineering, Classification of reactions, Rate equation and rate of reaction, Factors affecting rate of reaction, Temperature-dependency of rate constant from Arrhenius theory, Molecularity and order of reactions.
MODULE II: Non-Elementary Reactions
Difference between elementary and non- elementary reactions. Kinetic models and mechanisms for non-elementary reactions and types of reactors.
MODULE III: Homogeneous Reactions
Homogeneous Reactions: Interpretation of batch reactor data. Constant Volume batch reactor. Analysis: Differential method, Integral method, half-life method (Derivations in this module evaluated in the examination may be limited to first order reactions)
MODULE IV: Ideal Reactors

Design of Ideal Reactors: Concept of ideality, Development of design equations for batch, tubular and stirred tank reactors for constant volume reactions. Evaluation of rate equations from data obtained in these reactors. (Derivations in this module evaluated in the examination may be limited to first order reactions)
MODULE V: Basics Of Non-Ideal Flow
Importance & interpretation of RTD, C, E & F curves & Statistical interpretation

Text books

1. Octave Levenspeil, Chemical Reaction Engineering, 3rd Edition, John Wiley & Sons, 2001.
2. H. Scott Fogler, Elements of Chemical Reaction Engineering. 3rd Edition Prentice Hall, 2001.

Reference books

1. J.M. Smith, Chemical Engineering Kinetics -3rd Edition, McGraw Hill., 1984
2. K.A. Gavhane, Chemical Reaction Engineering-I, series Volume-1, Nirali Prakashan., ISBN- 13: 9788185790879, 2011.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1 (10 hours)	
1.1	Scope of Chemical Reaction Engineering	1
1.2	Classification of reactions	1
1.3	Rate equation and rate of reaction	1
1.4	Rate equation and rate of reaction	1
1.5	Factors affecting rate of reaction	1
1.6	Temperature-dependency of rate constant from Arrhenius theory.	1
1.7	Temperature-dependency of rate constant from Arrhenius theory.	1
1.8	Molecularity and order of reactions	1
1.9	Molecularity and order of reactions	1
1.10	Molecularity and order of reactions	1
	MODULE II (9 hours)	
2.1	Difference between elementary and non- elementary reactions	1
2.2	Difference between elementary and non- elementary reactions	1

2.3	Kinetic models and mechanisms for non-elementary reactions and types of reactors	1
2.4	Kinetic models and mechanisms for non-elementary reactions and types of reactors	1
2.5	Kinetic models and mechanisms for non-elementary reactions and types of reactors	1
2.6	Kinetic models and mechanisms for non-elementary reactions and types of reactors	1
2.7	Kinetic models and mechanisms for non-elementary reactions and types of reactors	1
2.8	Kinetic models and mechanisms for non-elementary reactions and types of reactors	1

2.9	Kinetic models and mechanisms for non-elementary reactions and types of reactors	1
MODULE III (9 hours)		
3.1	Interpretation of batch reactor data. Constant Volume batch reactor	1
3.2	Interpretation of batch reactor data. Constant Volume batch reactor	1
3.3	Differential method	1
3.4	Differential method	1
3.5	Differential method	1
3.6	Integral method	1
3.7	Integral method	1
3.8	half-life method	1
3.9	half-life method	
MODULE IV (10 hours)		
4.1	Concept of ideality	1
4.2	Development of design equations for batch reactor for constant volume reactions	1
4.3	Development of design equations for batch reactor for constant volume reactions	1
4.4	Development of design equations for stirred tank reactor for constant volume reaction.	1
4.5	Development of design equations for stirred tank reactor for constant volume reactions	1
4.6	Development of design equations for tubular reactor for constant volume reactions	1

4.7	Development of design equations for tubular reactor for constant volume reactions	1
4.8	Evaluation of rate equations from data obtained in these reactors	1
4.9	Evaluation of rate equations from data obtained in these reactors	1
4.10	Evaluation of rate equations from data obtained in these reactors	1
MODULE V (10 hours)		
5.1	Importance & interpretation of RTD	1
5.2	Importance & interpretation of RTD	1
5.3	C, E & F curves	1

5.4	C, E & F curves	1
5.5	C, E & F curves	1
5.6	Statistical interpretation	1
5.7	Statistical interpretation	1
5.8	Statistical interpretation	1
5.9	Statistical interpretation	1
5.10	Statistical interpretation	1

CO Assessment Sample Questions	
1	Define molecularity and order of a chemical reaction.
2	Distinguish between elementary and non-elementary reactions
3	Explain on different types of ideal reactors
4	The half-life period for a certain first order reaction is 2.5×10^3s. Determine the time taken for ¼ of the reactant to be left behind.
5	Explain the importance of RTD studies in non-ideal reactors.

SEVENTH SEMESTER

24CHP701	COMPUTER AIDED PROCESS DESIGN	L	T	P	J	S	C	Year of Introduction
		2	1	2	0	4	4	2024

Preamble: The objective of this course is to give a foundation for the undergraduates in the design of major equipments used in process industries for heat and mass transfer. This course includes sizing of equipment and selection of the internal parts. It also covers the use of standards and codes for the design of equipment.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Congregate the data from the literature, Handbook, Codebook etc.
CO 2	Interpret the literature data required for the functional design.
CO 3	Design the heat and mass transfer equipment.
CO 4	Select the details of accessories based on technical needs and availability.
CO 5	Decide on the incorporation of inherent safety standards.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO 5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	3	3										
CO 2	3	3	3	3								
CO 3	3	3	3					3				
CO 4	3	2										2
CO 5	3	2				3		3				

Assessment Pattern for Theory component

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Assessment Pattern for Lab component

Bloom's Category	Continuous Assessment Tools	
	Class work	Test1
Remember		
Understand	✔	✔
Apply	✔	✔
Analyse	✔	✔

Evaluate	✔	
Create	✔	

Mark Distribution of CIA							
Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Practical [P]		Total Marks
		Assignment	Test-1	Test-2	Class work	Lab Exam	
2-1-2-0	5	10	10	10	15	10	60

Total Marks distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	60	40	2.5 Hrs
End Semester Examination [ESE]: Pattern			
PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 3		2 questions will be given, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 40 marks. Marks: (1x 40 = 40 marks) Time: 2.5 hours	40
	Total Marks: 0	Total Marks: [1x 40 = 40 marks]	

SYLLABUS
MODULE I: Introduction and basic particle size analysis
DESIGN OF HEAT TRANSFER EQUIPMENT: Shell and Tube Heat exchanger, Single and Multiple effect Evaporator. DESIGN OF MASS TRANSFER EQUIPMENT: Sieve Plate Distillation Column, Packed Bed Absorption Column. NOTE: • The question paper contains two full design problems (40 Marks each)

for the equipment from the above listed and students should answer anyone.

- Perry's Chemical Engineers Handbook and IS Code 4503 for heat exchangers shall be allowed in the examination.
  Attested copies of Dühring's charts, Steam table, Nomographs, charts and data tables used in design taken from TEMA standard/ Other editions of
- Handbook shall be allowed in the examination.

Reference books

1. S B Thakore and B I Bhatt, Introduction to Process Engineering and Design, 3rd Edition, Tata McGraw-Hill, 2011.
2. Donald Q. Kern, Process Heat Transfer, McGraw Hill, 1997.
3. Robert E Treybal, Mass Transfer Operations, McGraw Hill, 1981.
4. R. H. Perry and D. W. Green, Chemical Engineering Handbook, 7th Edition, McGraw Hill, 1998.
5. J. M. Coulson and J. F. Richardson, Chemical Engineering, Vol. 6, Pergamon Press, 1993.
6. Shell and Tube Heat exchanger IS Code, IS 4503, BIS, New Delhi, 1969.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE 1		
1.1	A general introduction to design, chemical engineering design, equipment design and design profession discussing the design process and design constraints	1
1.2	Basic design procedure of heat transfer equipment, overall heat transfer coefficient and dirt factors	1
1.3	Shell and tube heat exchangers – construction details, selection, algorithm,	1
1.4	Design codes, mean temperature difference, general design considerations	1
1.5	Tube-side heat transfer coefficient and pressure drop	1
1.6	Shell-side heat transfer coefficient and pressure drop	1
1.7	Design problem of shell and tube heat exchanger	1
1.8	Design problem of shell and tube heat exchanger	1
1.9	Design problem of shell and tube heat exchanger	1
1.10	Design problem of shell and tube heat exchanger	1

1.11	Types of evaporators, Materials of construction	1
1.12	Design considerations	1
1.13	Design of single effect and multiple effect evaporators	1
1.14	Design problem of single effect and multiple effect evaporators	1
1.15	Design problem of single effect and multiple effect evaporators	1
1.16	Design problem of single effect and multiple effect evaporators	1
1.17	Design of distillation column, various design methods of distillation column	1
1.18	General design consideration of distillation	1
1.19	Plate efficiency, tray hydraulics of sieve trays	1
1.20	Design problem of a distillation column	1
1.21	Design problem of a distillation column	1
1.22	Design problem of a distillation column	1
1.23	Design problem of a distillation column	1
1.24	Design problem of a distillation column	1
1.25	Packed columns - type of packing	1
1.26	Packed bed height, column diameter,	1
1.27	Column internals	1
1.28	Design methods	1
1.29	Design problem of an absorption column	1
1.30	Design problem of an absorption column	1
1.31	Design problem of an absorption column	1
1.32	Design problem of an absorption column	1

LESSON PLAN FOR LAB COMPONENT

No.	Topic	No. of Hours	Experiment
1	Mixer, Heater and Pump.	2	Simulation of Mixer, Heater and Pump using ASPEN / MATLAB / UNISIM
2	Heat Exchanger	2	Simulation of Heat Exchanger using ASPEN / MATLAB / UNISIM
3	Flash Drum for Binary Mixture	2	Simulation of Flash Drum for Binary Mixture using ASPEN / MATLAB / UNISIM
4	Distillation Column	2	Simulation of Distillation Column using ASPEN / MATLAB / UNISIM
5	Refrigeration Gas Plant	2	Simulation of Refrigeration Gas Plant using ASPEN / MATLAB / UNISIM
6	Conversion Reactor	2	Simulation of Conversion Reactor using ASPEN / MATLAB / UNISIM
7	Equilibrium Reactor	2	Simulation of Equilibrium Reactor using ASPEN / MATLAB / UNISIM
8	Two Stage Compression System	2	Simulation of Two Stage Compression System using ASPEN / MATLAB / UNISIM
9	Absorption Column	2	Simulation of Absorption Column using ASPEN / MATLAB / UNISIM
10	Introduction to Dynamic Simulation	2	Introduction to Dynamic Simulation

CO assessment sample question	
1	Design a forward feed, double effect, long tube vertical evaporator unit to Concentrate 9000 kg/hr of 10% aqueous NaOH solution entering at 25 ^{o}C to a final concentration of 40%. Saturated steam is available at 172.2 kPa and the pressure in the second evaporator is 11.7 kPa. Boiling point elevation of the solution is 6 ^{o}C in both effects. The overall heat transfer coefficient for both effects is 1500 W/m^{2}K. Specific heat of aqueous NaOH solution in J/kg^{o}C is given by Cp = -1841.2 x + 4110, where x is weight fraction of NaOH. Calculate the tube sheet diameter. Estimate the size of vapour release drum with wire-mesh entrainment separator.

24CHP702	BIOLOGY & BIOCHEMICAL ENGINEERING	L	T	P	J	S	C	Year of Introduction
		2	1	2	0	4	4	2024

Preamble: The course amalgamates the facts from both chemical engineering and biological engineering. It mainly deals with the design, construction, and advancement of unit processes that involve biological organisms or organic molecules. This subject has various applications in the areas of biofuels, pharmaceuticals, agriculture, food sciences, biotechnology and water treatment processes. This course would enable students to gain a basic knowledge on application of the biological processes to make useful chemicals, which can be utilized in the aforesaid areas.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Describe different types of cells, classification of kingdom Protista and potential of chemicals of life.
CO2	Interpret kinetics of enzyme-catalyzed reactions.
CO3	Describe Immobilized enzyme technology and metabolic pathways within the cell.
CO4	Explain heat and mass transfer principles in bioreactors and bioprocess.
CO5	Describe design and operation of a fermentation process and use of sensors.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3		2									2
CO2	3	3	2	2								2
CO3	3		2			2						2
CO4	3		2			2						2
CO5	3		2	2		2						2

Assessment Pattern for Theory component

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Assessment Pattern for Lab component		
Bloom's Category	**Continuous Assessment Tools**	
	Class work	**Test1**
Remember		
Understand	✔	✔
Apply	✔	✔
Analyse	✔	✔
Evaluate	✔	
Create	✔	

Mark Distribution of CIA

Course Structure [L-T-P-J] 2-1-2-0	**Theory [L- T]**				**Practical [P]**		**Total Marks**
	Attendance	**Assign ment**	**Test-1**	**Test-2**	**Class work**	**Lab Exam**	
	5	10	10	10	15	10	60

Total Marks distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	60	40	2.5 Hours

End Semester Examination [ESE]: Pattern

PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 2		2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x 8 = 40marks) Time: 2.5 hours	40
	Total Marks: 0	Total Marks: [5x8 = 40 marks]	

SYLLABUS
MODULE I: Microbiology and chemicals of life
Micro Biology, Cell theory, Structure of cells, Cell fractionation, protist kingdom and their distinguishing characteristics. Chemicals of life: repetitive and non-repetitive biopolymers - lipids, sugars and polysaccharides, amino acids and proteins. Protein structure, nucleotides- RNA and DNA.
MODULE II: Kinetics of Enzyme catalyzed reactions
Kinetics of Enzyme catalyzed reactions: simple enzyme kinetics with one or twosubstrates, Michaelis - Menten Kinetics, Evaluation of parameters in Michaelis – Menten equation, Substrate concentration dependence of enzyme catalysed reactions: substrate activation and inhibition, Modulation and regulation of enzyme activity – competitive and uncompetitive inhibition. Enzyme specificity and enzyme specificity hypotheses. Batch cultivation - growth cycle (lag, exponential, stationary and death phase).
MODULE III: Enzyme Immobilization and Metabolic pathways
Enzymes of industrial importance. Immobilized enzyme technology: enzyme immobilization, medical and analytical applications of immobilized enzymes. Metabolic pathways and energetics of the cell: Metabolic reaction coupling: ATP, ADP and NAD. Oxidation and reduction- Coupling via NAD. Embden-Meyerhof pathway (EMP), Respiration - TCA cycle. Transport across cell membranes - passive transport, active transport and facilitated diffusion.
MODULE IV: Transport phenomena in Bioprocess and bioreactors
Transport phenomena in BBioprocess system-Gas-liquid mass transfer in cellular system - basic mass transfer and concepts - rates of metabolic oxygen utilization – determination of oxygen transfer rates-mass transfer across free falling or raising bubble. Biochemical reactors-specifications Continuous stirred tank bioreactor, bubble column bioreactor, Airlift bioreactors, Fluidized bed bioreactors, Packed bed bioreactor.
MODULE V: Fermentation technology and biosensors
Fermentation technology, medium formulation, design and operation of a typical aseptic, aerobic fermentation process. Different configurations for fermenters. Concept of biosensors. Physical and chemical sensors, gas analysis sensors.

Text books

1. James E. Bailey and David F. Ollis., "Biochemical Engineering Fundamentals". McGraw Hill International Editions.
2. D G Rao., "Introduction to Biochemical Engineering", Tata Mc Graw Hill.
3. CHEMICAL ENGINEERING3. Michael L Shuler and Frikret Khargi., "Bioprocess Engineering Basic Concepts" PHI Publications.

Reference books

1. H. W.Blanch & D.S. Clark, Marcel Dekker, Biochemical Engineering by, Inc., 1997.
2. Paulin M Doran, Bioprocess Engineering principles ISBN-978-0-12220851 5

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE I (7 hours)		
1.1	Structure of cells, prokaryotic and eukaryotic cells	1
1.2	Cell fractionation	1
1.3	Protist kingdom and their distinguishing characteristics	1
1.4	Classification of microorganisms belonging to the kingdom of protists	1
1.5	Chemicals of life: repetitive and non-repetitive bio polymers Lipids, Sugars and polysaccharides	1
1.6	Amino acids and proteins, Protein structure, Nucleotides RNA and DNA	1
1.7	Amino acids and proteins, Protein structure, Nucleotides RNA and DNA	1
MODULE II (9 hours)		
2.1	Enzyme substrate complex and enzyme action simple enzyme kinetics with on or two substrates	1
2.2	Derivation of Michaelis - Menten Kinetics, evaluation of parameters in MM kinetics	1
2.3	Derivation of Michaelis - Menten Kinetics, evaluation of parameters in MM kinetics	1
2.4	Description of Substrate activation and inhibition	1
2.5	Modulation and regulation of enzyme activity- mechanism of reversible enzyme modulation	1
2.6	Derivation of competitive inhibition	1
2.7	Derivation of uncompetitive inhibition	1

2.8	Different factors affecting enzyme activity, Enzyme specificity and enzyme specificity hypotheses	1
2.9	Batch cultivation - growth cycle (lag, exponential, stationary and death phase)	1
MODULE III (8 hours)		
3.1	Important enzymes of industrial importance, Different methods for Enzyme immobilization	1
3.2	Medical and analytical applications of immobilized enzymes	1
3.3	Metabolic reaction coupling : ATP, ADP and NAD	1
3.4	Oxidation and reduction- Coupling via NAD	1
3.5	Embden-Meyerhof pathway (EMP), Respiration - TCA cycle	1
3.6	Embden-Meyerhof pathway (EMP), Respiration - TCA cycle	1
3.7	Transport across cell membranes - passive transport, active transport and facilitated diffusion.	1

3.8	Transport across cell membranes - passive transport, active transport and facilitated diffusion.	1
MODULE IV (6 hours)		
4.1	Gas-liquid mass transfer in cellular system – basic mass transfer and concepts, rates of metabolic oxygen utilization	1
4.2	Determination of oxygen transfer rates-mass transfer across free falling or raising bubble	1
4.3	Specifications and operational stages in a bioreactor, Continuous stirred tank bioreactor, bubble column bioreactor	1
4.4	Specifications and operational stages in a bioreactor, Continuous stirred tank bioreactor, bubble column bioreactor	1
4.5	Airlift bioreactors, Fluidized bed bioreactors,	1
4.6	Airlift bioreactors, Fluidized bed bioreactors	1
MODULE V (6 hours)		
5.1	Medium formulation in fermentation	1
5.2	Design and operation of a typical aseptic, aerobic fermentation process.	1
5.3	Design and operation of a typical aseptic, aerobic fermentation process.	1
5.4	Alternate bioreactor configurations	1

5.5	Sensors of the physical environment, gas analysis sensors	1
5.6	Sensors of the physical environment, gas analysis sensors	1

LESSON PLAN FOR LAB COMPONENT

No.	Topic	No. of Hours	Experiment
1	Cell culture	2	Isolation of high yielding microbial strains for the production of commercially important enzymes.
2	Chemicals of Life	2	Estimation of different macromolecules by visible spectrophotometer
2	Chemicals of Life	2	Verification of Lambert – Beer's Law by UV – VIS spectrophotometer.
4	Chemicals of Life	2	Determination of optical activity of simple sugars by polarimetry
5	Enzyme kinetics	2	Determination of enzyme activity and specific activity.
6	Enzyme kinetics	2	Characterization of enzymes-Effect of pH, temperature and inhibitors on enzyme activity etc.
7	Enzyme kinetics	2	Development of enzyme assay methods.
8	Protein purification	2	Purify a target protein from a complex mixture using techniques such as chromatography. Assess the purity and yield of the isolated protein.
9	Bioremediation assessment	2	Design and conduct a bioremediation experiment using microorganisms to degrade a specific pollutant. Monitor changes in pollutant concentration over time.
10	Immobilization of enzymes	2	Immobilization of enzymes –Different Techniques such as adsorption, entrapment, encapsulation and crosslinking.

CO Assessment Sample Questions

1	Compare eukaryotic and prokaryotic cells in terms of internal structure and functions
2	The following initial rate data were obtained as a function of initial substrate concentration. Evaluate the Michaelis- Menten kinetic parameters by employing the Eadie-Hofstee plot.
3	Explain different methods for immobilization of enzymes.
4	Explain the oxygen transfer in fermentation process with the help of mass transfer coefficient.
5	Explain the medium formulation in a fermentation process

24CHR705	Major Project	L	T	P	J	S	C	Year of Introduction
		0	0	14	0	14	7	2024

Preamble: Research based Mini Project focuses on strengthening the understanding of student's fundamental concepts through the application of theoretical concepts and to boost their skills and widen the horizon of their thinking in research. The course will provide an opportunity to identify technology/research gaps and propose innovative/creative solutions. The course will develop skills in doing literature survey, technical presentation and report preparation.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Analyze existing literature in the chosen field or conduct need based analysis and identify research gaps for further investigation.
CO2	Conceive a research statement and formulate research objectives.
CO3	Design and implement a well-structured research plan, outlining the key variables, hypotheses and experimental/analytical methods required to address the research questions.
CO4	Interpret results effectively to draw meaningful conclusions.
CO5	Prepare a technical report and make effective presentations.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO 11	PO12
CO1	3	3		2				3	3			3
CO2	3	3		3					3			3
CO3	3	3	3	3	1				3	3	2	3
CO4	3	2	3						3	3		3
CO5	3							3	3	3		

Assessment Pattern

Bloom's Category	Continuous assessment tools		
	Evaluation 1	Evaluation 2	Evaluation 3
Remember			
Understand	✔	✔	✔
Apply	✔	✔	✔
Analyse	✔	✔	✔
Evaluate		✔	✔
Create		✔	✔

Mark Distribution of CIA						
Course Structure [L-T-P-J]	Project guide	Interim Evaluation	Draft Report	Final Report	Final Evaluation	Total Marks
0-0-12-0	25	25	5	10	35	100

Total Mark distribution	
Total Marks	**CIA (Marks)**
100	**100**

General guidelines

- **Choosing a topic**

  Research based mini project shall be executed as a group activity where each group can have a maximum of four students and shall identify a topic of interest in consultation with Mini Project Coordinator that shall lead to their dissertation/final year project. Review the literature and gather information pertaining to the chosen topic. State the objectives and develop a methodology to achieve the objectives. Carryout the design / fabrication / synthesis / analysis / development of codes or programs to achieve the objectives.

- **Evaluation pattern**

  The progress of the Research based Mini Project is evaluated based on three reviews, two interim reviews and a final review. Students must submit a report during the final review. Credits can be assigned to a student for research based mini project if he/she earns a pass grade in the final review.

- **Evaluation committee**

  Continuous Internal Evaluation (CIE) Committee shall comprise of three members. Guide shall be one member in the CIE committee. Final Evaluation Committee shall comprise of three members- department project coordinator, guide and a member nominated by Head of the Department.

SEVENTH SEMESTER

PROFESSIONAL ELECTIVE-3

24CHE713	MUNICIPAL SOLID AND BIOMEDICAL WASTE MANAGEMENT	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: This course provides a comprehensive overview of waste management practices, covering solid waste characteristics, disposal techniques, biomedical waste categorization, and the development of effective waste management policies.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Describe solid waste types and influencing factors.
CO2	Develop efficient solid waste collection and processing systems.
CO3	Apply appropriate disposal methods considering sustainability and regulations.
CO4	Manage biomedical waste through proper categorization and treatment.
CO5	Develop comprehensive waste management plans with stakeholder engagement and economic feasibility.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3						3					
CO2	2					2				3		
CO3	2					2	3	2	3			
CO4	2					2		3				
CO5	2					3			3		3	3

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	**40**	**60**	**3 Hrs.**

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Introduction to Waste Management (7 Hrs.)

Understanding the concept of waste management, types of solid waste, Properties of Solid wastes, Waste generation, Sampling and analysis, Characteristics of solid wastes - Energy content, Chemical content, Estimation of chemical composition of a solid waste sample. Generation rates - Factors affecting generation rates.

MODULE II: Municipal Solid Waste (MSW) Management (8 Hrs.)

Collection of solid waste, On-site storage methods-containers, their type, size and location, Collection Systems-Vehicles, Types of collection system – HCS, SCS, Determination of vehicle and labor requirements, Collection routing, route balancing and transfer stations, Transfer methods, Processing methods.

MODULE III: Municipal solid waste disposal (8 Hrs.)

Disposal methods such as sanitary landfill –methods, leachate in landfills – control of leachate movement, Gas movement – control, Design and operation of landfills, Landfarming, deep well injection etc.

MODULE IV: Biomedical Waste (BMW) Management (6 Hrs.)

Classification and categorization of biomedical waste, Risks associated with improper BMW management, Segregation, collection, and storage of BMW, Treatment and disposal methods for BMW, Regulatory requirements and guidelines for BMW management.

MODULE V: Waste Management Planning and Policy (6 Hrs.)

Development of waste management plans for municipalities and healthcare facilities, Stakeholder engagement and community participation in waste. Management, Economic considerations and feasibility analysis for waste management projects, Policy frameworks and governance for effective waste management, Case studies highlighting

successful waste management policies and strategies.
Text books 1. Howard S.Peavy, Donald R.Rowe, George Tchobanoglous, Environmental Engineering, McGraw Hill. New York, 1985. 2. Frank Kreith, George Tchobanoglous, Handbook of Solid Waste Management, McGraw Hill Publishers, 2002
Reference books 1. P.Aarne Vesilind and William Worrell, Solid waste Engineering, Cengage Learning, Asia Pte Limited, 2012. 2. Gerard Kiely, Environmental Engineering, McGraw Hill, New Delhi,2008. 3. Nicholas P. Cheremisinoff, Handbook of Solid Waste Management and Waste Minimization Technologies, Butterworth Heinemann,2002. 4. Luis F. Diaz, George M. Savage, Linda L. Eggerth, Larry, Rosenberg, Solid Waste Management, United Nations Environment Programme, Paris, 2005.

COURSE CONTENTS AND LECTURE SCHEDULE		
No.		**No. of Hours**
	MODULE I	
1.1	Understanding the concept of waste management	1
1.2	types of solid waste, Properties of Solid wastes	1
1.3	Waste generation, Sampling and analysis, Characteristics of solid wastes	1
1.4	Waste generation, Sampling and analysis, Characteristics of solid wastes	1
1.5	Energy content, Chemical content	1
1.6	Estimation of chemical composition of a solid waste sample	1
1.7	Generation rates - Factors affecting generation rates.	1
	MODULE II	
2.1	Collection of solid waste	1
2.2	On-site storage methods-containers, their type, size and location	1
2.3	On-site storage methods-containers, their type, size and location	1
2.4	Collection Systems-Vehicles, Types of collection system –HCS,SCS	1
2.5	Collection Systems-Vehicles, Types of collection system –HCS,SCS	1
2.6	Determination of vehicle and labour requirements, Collection routing, route balancing and transfer stations	1
2.7	Transfer methods, Processing methods	1
2.8	Transfer methods, Processing methods	1
	MODULE III	
3.1	Disposal methods such as sanitary landfill –methods,	1

3.2	leachate in landfills, control of leachate movement,	1
3.3	leachate in landfills, control of leachate movement	1
3.4	Gas movement – control	1
3.5	Gas movement – control	1
3.6	Design and operation of landfills	1
3.7	Design and operation of landfills	1
3.8	Landfarming, deep well injection etc.	1
	MODULE IV	
4.1	Classification and categorization of biomedical waste	1
4.2	Risks associated with improper BMW management,	1
4.3	Segregation	1
4.4	collection, and storage of BMW, Treatment and disposal methods for BMW	1
4.5	collection, and storage of BMW, Treatment and disposal methods for BMW	1
4.6	Regulatory requirements and guidelines for BMW management.	1
	MODULE V	
5.1	Development of waste management plans for municipalities and healthcare facilities	1
5.2	Stakeholder engagement and community participation in waste management	1
5.3	Economic considerations and feasibility analysis for waste management projects,	1
5.4	Economic considerations and feasibility analysis for waste management projects	1
5.5	Policy frameworks and governance for effective waste management	1
5.6	Case studies highlighting successful waste management policies and strategies	1

CO Assessment Sample Questions	
1	Name major contributors to solid waste generation and provide examples
2	Explain the significance of efficient solid waste collection methods for sustainability
3	Devise an appropriate solid waste disposal strategy for an urban area, justifying your choice
4	Analyze risks linked to improper biomedical waste management and evaluate their implication
5	Assess economic feasibility of waste management projects, comparing costs and benefits
6	Develop a comprehensive waste management plan with stakeholder engagement strategies

24CHE723	Hazard Analysis and Risk Management	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: In the dynamic and complex domain of chemical process industries, safety stands as a paramount consideration. This subject serves as a pivotal exploration into the systematic identification, analysis and management of potential hazards in chemical process industries.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Identify and assess the risk and hazards of process and operation.
CO 2	Explain different types of indices used in hazard surveys.
CO 3	Explain different types of hazard identification and risk assessment techniques in the workplace.
CO 4	Determine the main process hazard analysis tools used and compare their uses, benefits and limitations
CO 5	Give recommendations based on risk decisions by applying LOPA methodology.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	3	2	3			2						
CO 2	3	2	2			2						
CO 3	3		2			2						
CO 4	3		2			2						
CO 5	3		2			2	2	2				

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Mars
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Hazard Identification techniques

Hazard and risk-Major industrial hazards-Structure of hazard identification and risk assessment. Identification of hazards: Inventory analysis, What If analysis, The Dow Fire and Explosion Hazard Index, The Mond Index, Preliminary hazard analysis, Hazard and Operability study (HAZOP), Case studies.

MODULE II: Plant availability and process reliability

Plant availability and process reliability: The reliability function, probability relationships, Failure rate, bathtub curve, simple reliability estimation, MTBF and MTTF, Ways of improving plant availability.
Fault tree analysis – logic symbols, minimal cut set, logic gates, fault tree quantification. Event tree analysis: event tree construction, advantages and disadvantages of ETA. Failure mode and Effect Analysis (FMEA) – methodology, criticality analysis

MODULE III: Consequence modelling

Source models – discharge rate models Dispersion models: Plume model
Explosions and fires – Vapour cloud explosions, BLEVE, flash fires, Pool fires, jet fires.
Software application for effect and damage calculations: ALOHA and PHAST

MODULE IV: Measurement, Calculation, and Presentation of Risk Estimates

Steps in Chemical Process Quantitative risk analysis, Accepted and imposed risk, Risk perception, ALARP, Acceptance criteria for risk, Presentation of measures of risk– risk contour, F-N curve. Calculation of individual risk and Societal risk
MODULE V: Layer of Protection Analysis
Layer of Protection Analysis (LOPA)-LOPA methodology- Scenario development. Independent protection layers – IPL criteria, allocation of IPL credit –safety instrumented system, safety instrumented function. Risk tolerance criteria-Safety integrity level (SIL) assignment, Interpreting LOPA results -risk decisions and making recommendations.
Text books 1. Daniel A Crowl& Joseph F Louvar, Chemical Process Safety, Second Edition, Prentice-Hall. 2. L.S. Srinath, Reliability Engineering, Affiliated East-West Press, New Delhi, (2005).
Reference books 1. Sam Mannan (Editor). Lee's Loss Prevention in the Process Industries. (Fourth edition). Butterworth-Heinemann Ltd., UK. (2012). 2. AIChE/CCPS. Guidelines for Chemical Process Quantitative Risk Analysis. (second edition). Centre for Chemical Process Safety, American Institute of Chemical Engineers, New York. (2000). 3. Bob Skelton. Process safety analysis: An Introduction, Institution of Chemical Engineers. (1997) 4. AIChE/CCPS. Guidelines for Hazard Evaluation Procedures. (Second edition). Centre for Chemical Process Safety, American Institute of Chemical Engineers, New York. (1992).

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE 1 (6 hours)		
1.1	Hazard and risk-Major industrial hazards-Structure of hazard identification and risk assessment.	1
1.2	Inventory analysis, What If analysis	1
1.3	The Dow Fire and Explosion Hazard Index	1
1.4	The Mond Index, Preliminary hazard analysis	1
1.5	Hazard and Operability study (HAZOP)	1
1.6	Case studies	1
MODULE II (10 hours)		
2.1	The reliability function, probability relationships	1
2.2	Failure rate, bathtub curve	1
2.3	Simple reliability estimation	1

2.4	MTBF and MTTF	1
2.5	Ways of improving plant availability	1
2.6	Fault tree analysis – logic symbols, minimal cut set, logic gates, fault tree quantification.	1
2.7	Fault tree analysis – logic symbols, minimal cut set, logic gates, fault tree quantification.	1
2.8	Event tree analysis –event tree construction, advantages and disadvantages of ETA.	1
2.9	Event tree analysis-event tree construction, advantages and disadvantages of ETA.	1
2.10	Failure mode and Effect Analysis (FMEA) – methodology, criticality analysis	1
MODULE III (8hours)		
3.1	Source models – discharge rate models	1
3.2	Source models – discharge rate models	1
3.3	Dispersion models: Plume model	1
3.4	Model for Vapour cloud explosions	1
3.5	Model for BLEVE	1
3.6	Models for flash fire and pool fire	1
3.7	Model for jet fire	1
3.8	Software application for effect and damage calculations: ALOHA and PHAST	1
MODULE IV (6 hours)		
4.1	Steps in Chemical Process Quantitative risk analysis	1
4.2	Accepted and imposed risk, Risk perception	1
4.3	ALARP, Acceptance criteria for risk	1
4.4	Presentation of measures of risk – risk contour, F-N curve	1
4.5	Calculation of individual risk	1
4.6	Calculation of Societal risk	1
MODULE V (5 hours)		
5.1	Layer of Protection Analysis (LOPA)-LOPA methodology-Scenario development.	1
5.2	Independent protection layers – IPL criteria, allocation of IPL credit	1

5.3	safety instrumented system, safety instrumented function	1

5.4	Risk tolerance criteria-Safety integrity level (SIL) assignment	1
5.5	Interpreting LOPA results -risk decisions and making recommendations.	1

CO Assessment sample Questions	
1	Explain in detail about classification of hazards in chemical process Industries.
2	Explain ALARP triangle and give its significance in risk reduction
3	Construct an event tree for LPG release from a storage tank located in an LPG bottling plant. Assume frequency values for different situations
4	A gas with a molecular weight of 30 is used in a particular process. A source model study indicates that for a particular accident outcome 1.0 kg of gas will be released instantaneously. The release will occur at ground level. The plant fence line is 500 m away from the release. Determine: (i) The time required after the release for the center of the puff to reach the plant fence line. Assume a wind speed of 2 m/s. (ii) The maximum concentration of the gas reached outside the fence line.
5	Determine the consequence frequency for a cooling water failure if the system is designed with two IPLs. The IPLs are human interaction with 10-min response time [PFD = 10^{-1} per year] and a basic process control system (BPCS) [PFD = 10^{-1} per year]. Frequency of cooling water failure is 0.1 per year.

24CHE733	COMPUTATIONAL FLUID DYNAMICS	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: Computational Fluid Dynamics (CFD) is used as a research and design tool. CFD can be applied to majority of engineering problems such as chemical and mineral processing, environmental problems, aerospace fields, naval architecture and biomedical engineering. It can be used as an education tool to learn basic thermal-fluid science.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Describe basic CFD concepts and procedures to develop CFD solutions.
CO2	Apply knowledge of basic science and engineering fundamentals to solve practical problems.
CO3	Solve the governing equations for fluid flow numerically.
CO4	Implement grid generation, assess stability and conduct a grid convergence assessment.
CO5	Apply turbulence models to engineering fluid flow problems.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO 12
CO1	3	3	3	2								
CO2	3	3	3	2								
CO3	3	3	3	2	2							
CO4	3	3	3	2	2						3	
CO5	3	3	3	2	2						3	

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 hours

<u>End Semester Examination [ESE]: Pattern</u>

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Introduction (8 hours)

Introduction: Need of CFD as an analysis tool, comparison of experimental, theoretical and computational approaches, Applications – automobile, environmental engineering, chemical engineering, CFD software packages and tools. CFD solution procedure: pre-processing, numerical solution – CFD solver, post processing. Ordinary and partial differential equations, classification of partial differential equations (PDE): physical classification – equilibrium and marching problems; mathematical classification – hyperbolic, parabolic and elliptic PDEs, well posed problems.

MODULE II: Review of governing equations (6 hours)

Review of governing equations: Continuity equation, Momentum equation, Energy equation, Navier – Stokes equation, generic form of governing equations, boundary conditions - types of boundary conditions: Neumann, Dirichlet, Robin, mixed boundary condition. Turbulence modeling – k-ε turbulence model.

MODULE III: Basic concepts of CFD (6 hours)

Basic concepts of CFD: Introduction to discretization, Finite difference approximation of a derivative, discretization of differential equations using finite differences, consistency, convergence and stability (concepts alone), concept of explicit and implicit methods, Crank Nicholson scheme FTCS only.

MODULE IV: Finite volume discretization (8 hours)

Finite Volume Discretization: Diffusion problem, convection-diffusion problem, properties of discretization schemes – conservativeness, boundedness, transportiveness. Solution to discretized equations: TDMA, Jacobi, Gauss-Seidel, Gauss elimination methods.

MODULE V: Detailed study of Navier-Stokes Equation (8 hours)
Detailed study of Navier stokes Equation-Solution of the Navier Stokes Equations-Discretization of convective, viscous, pressure and body force terms-conservation properties-grid arrangement colocated and staggered pressure equation and its solutions—implicit and explicit methods-implicit pressure correction methods-Fractional Step method-SIMPLE algorithm for a colocated Variable arrangement. Grid generation: structured and unstructured grid, grid spacing, Cartesian and curvilinear grids, grid independence, hybrid grid.

Text books

1. John C Tannehill, D A Anderson, R H Pletcher, Computational fluid Mechanics and Heat transfer, , Taylor & Francis Publishers.
2. John D Anderson, Computational Fluid Dynamics – The basics with applications, McGrawHill.
3. H Versteeg, M Malasekara, An introduction to Computational Fluid Dynamics, Pearson.

Reference books

1. Vivek V. Ranade, Computational Fluid Dynamics for Reactor Engineering De Gruyter, 1995.
2. K Muralidhar and Sundararajan, Computational Fluid flow and Heat transfer, Suhas V Patankar, Numerical heat transfer and fluid flow.
3. Pradeep Niyogi, S K Chakrabarthy, M K Laha, Pearson, Introduction to Computational Fluid Dynamics.
4. Gautam Biswas, Somenath Mukherjee, Narosa, Computational Fluid Dynamics.
5. Sreenivas Jayanti, Computational fluid dynamics for Engineers and Scientists, Springer.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE I	
1.1	Need of CFD, advantages of CFD method, applications	1
1.2	solution procedure – pre-processing, solver, post processing – geometry, meshing, implementation of boundary conditions etc., computer graphic techniques	1
1.3	solution procedure - pre-processing, solver, post processing – geometry, meshing, implementation boundary	1

	conditions etc., computer graphic techniques	
1.4	PDE, classification,	1
1.5	Equilibrium & marching problems	1
1.6	Hyperbolic, elliptic, parabolic PDE	1
1.7	Well posed problems	1
1.8	Well posed problems	1
	MODULE II	
2.1	Continuity, momentum and energy equation	1
2.2	Continuity, momentum and energy equation	1
2.2	Navier – Stokes equation	1
2.3	Generic form of governing equation	1
2.4	Boundary conditions – need, various types with examples	1
2.5	Turbulence modelling - k-ε turbulence model	1
2.6	Turbulence modelling - k-ε turbulence model	1
	MODULE III	
3.1	Discretization, finite difference approximation of a derivative, truncation error	1
3.2	Discretization of equations using finite difference	1
3.3	Concept of consistency, convergence and stability	1
3.4	Explicit and implicit methods	1
3.5	Crank- Nicolson scheme - FTCS	1
3.6	Crank- Nicolson scheme - FTCS	1
	MODULE IV	
4.1	Diffusion problem	1
4.2	Convection-diffusion problem	1
4.3	Properties of discretization schemes - conservativeness, boundedness, transportiveness.	1
4.4	Solution methods – TDMA, Jacobi	1
4.6	Solution methods – TDMA, Jacobi	1
4.7	Gauss Siedel and Gauss elimination	1
4.8	Gauss Siedel and Gauss elimination	1
	MODULE V	
5.1	Solution of Navier Stokes equations	1

5.2	Discretization of convective, viscous, pressure and body force terms.	1
5.3	Discretization of convective, viscous, pressure and body force terms.	1
5.4	Conservation properties-grid arrangement.	1
5.5	Staggered pressure equation and its solutions—implicit and explicit methods –	1
5.6	Implicit pressure correction method	1
5.7	Fractional Step method-SIMPLE algorithm for a colocated Variable arrangement.	1
5.8	Grid generation – structured & unstructured grids, grid spacing, Cartesian and curvilinear grids, grid independence, hybrid grid.	1

CO Assessment Sample Questions	
1	Describe the main elements involved in a complete CFD analysis.
2	Determine velocity profile for steady incompressible laminar flow through the space between two parallel plates.
3	Explain implicit and explicit methods.
4	Write a note on grid independence.
5	Discuss on k-ε turbulence model.

24CHE743	**PIPELINE TRANSPORTATION OF OIL & GAS**	**L**	**T**	**P**	**J**	**S**	**C**	**Year of Introduction**
		3	**0**	**0**	**0**	**3**	**3**	**2024**

Preamble: This course provides students with a comprehensive understanding of oil and gas pipeline transportation, covering various aspects such as pipeline design, construction, pressure drop estimation, pumps and compressors, and pipeline issues. The course is industry-relevant, focusing on practical skills, safety and compliance, problem-solving, and technological awareness. It equips students with the foundational knowledge for careers in oil and gas, preparing them for real-world scenarios and ensuring compliance with regulations. The course also focuses on enhancing analytical and problem-solving skills through exposure to pipeline transportation challenges.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Explain the basis of pipeline operations for transporting oil and gas.
CO 2	Apply various equations to calculate pressure drop in oil and gas pipelines.
CO 3	Describe the laying and construction activities of pipelines.

CO 4	Explain the types and characteristics of pumps and compressors used for transportation of oil and gas.
CO 5	Identify the various issues associated with pipeline transport and methods to mitigate them.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	3											1
CO 2	3	2				2	2					1
CO 3	3									2		1
CO 4	3											1
CO 5	3					2						1

Assessment Pattern

Bloom's Category	**Continuous Assessment Tools**			**End Semester Examination**
	Test1	**Test 2**	**Other tools**	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyze			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	**Attendance**	**Theory [L- T]**			**Total Marks**
		Assignment	**Test-1**	**Test-2**	
3-0-0-0	5	15	10	10	40

Total Mark distribution

Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	**40**	**60**	**3 hrs**

<u>End Semester Examination [ESE]: Pattern</u>

PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS
MODULE I : Basics of Pipeline Operations (6 hr)
Methods of Transporting Oil & Gas Importance of Pipelines, Pipeline Systems Design Life of Pipelines, Growth of Pipeline Industry in India, Codes and Standards used in Pipeline industry, Properties of Gas and Liquid, SI and USCS System Standard Conditions. Treatment techniques for removal of sulfur compounds to improve performance.
MODULE II : Pressure Drop Estimations (8 hr)
Gas flow equations, Transmission Factor, Head in Pipelines (Gradient and Elevation), Oil Flow equations
MODULE III : Pipeline Construction (7 hr)
Overview of Oil and Gas Pipelines, Regulatory Framework and Safety Standards, Material Selection and Pipeline Components, Construction Techniques and Challenges Pipe line Laying, Pipe Specifications, Route Surveying, Trenching, Welding, Wrapping, Pig launchers and receivers
MODULE IV : Pumps and Compressors (7 hr)
Types of Pumps and Compressors, Pumps and Compressors Characteristics, Single and Multistage pumps and compressors, Congealing
MODULE V : Pipeline issues and Mitigation Measures and future trends (6 hr)
Challenges in Pipeline Transportation, Corrosion and Integrity Management, Managing High Pressure Systems, External Threats and Security Measures. Future Trends and Innovations in Pipeline Technology: Automation and Remote Monitoring, Advanced Materials and Coatings, Emerging Technologies in Pipeline Transportation. Wax, Scaling, Condensate, Corrosion, Thermal Variations in Pipelines, Automation and SCADA
Text books 1. Menon, E. S. (2005). Gas pipeline hydraulics, CRC Press, Taylor and Francis Group, Boca Raton, FL. 2. Menon, E. S. (2005). Liquid pipeline hydraulics, CRC Press, Taylor and Francis Group, Boca Raton, FL. 3. E.W. McAllister (2002). Pipeline Rules of Thumb Handbook, Gulf Professional Publishing
Reference books 1. Duraid, A. (2010).A Quick Guide to Pipeline Engineering, Wood hand Publishing, Cambridge, England 2. Arnold, K. (1989). Surface Production Operations. Gulf Publishing Company, Houston, Texas 3. George A. Antaki (2003) Piping and Pipeline Engineering:Design, Construction, Maintenance, Integrity and Repair, Marcel Dekker Inc.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1	

1.1	Methods of Transporting Oil &Gas	1
1.2	Importance of Pipelines, Pipeline Systems	1
1.3	Design Life of Pipelines, Growth of Pipeline Industry in India	1
1.4	Codes and Standards used in Pipeline industry,	1
1.5	Properties of Gas and Liquid, SI and USCS System Standard Conditions	1
1.6	Treatment techniques for removal of sulfur compounds to improve performance.	1
	MODULE II	
2.1	Gas flow equations	1
2.2	Gas flow equations	1
2.3	Gas flow equations	1
2.4	Transmission Factor	1
2.5	Head in Pipelines (Gradient and Elevation)	1
2.6	Head in Pipelines (Gradient and Elevation)	1
2.7	Oil Flow equations	1
2.8	Oil Flow equations	1
	MODULE III	
3.1	Overview of Oil and Gas Pipelines, Regulatory Framework and Safety Standards	1
3.2	Material Selection and Pipeline Components, Construction Techniques and Challenges	1
3.3	Pipe line Laying and Pipe Specifications Route Surveying	1
3.4	Trenching	1
3.5	Welding	1
3.6	Wrapping	1
3.7	Pig launchers and receivers	1
	MODULE IV	
4.1	Types of Pumps and Compressors	1
4.2	Pumps and Compressors Characteristics	1
4.3	Single stage pumps	1
4.4	Multistage pumps	1
4.5	Single stage Compressors	1
4.6	Multistage compressors	1
4.7	Congealing	1
	MODULE V	

5.1	Pipeline issues: Wax, Scaling and corrosion	1
5.2	Thermal Variations in Pipelines	1
5.3	Challenges in Pipeline Transportation, Corrosion and Integrity Management.	1
5.4	Managing High-Pressure Systems, External Threats and Security Measures.	1
5.5	Future Trends and Innovations in Pipeline Technology: Automation and Remote Monitoring, Advanced Materials and Coatings, Emerging Technologies in Pipeline Transportation.	1
5.6	Automation and SCADA	1

CO Assessment Sample Questions	
1	Explain the terms Solution GOR and API.
2	Explain the terms in the modified Colebrook White equation and describe the significance of the equation in pipeline design.
3	Describe open trench pipe laying method.
4	Distinguish between centrifugal and reciprocating pumps.
5	List and explain any two pipeline issues and methods to mitigate them.

24CHE753	ELECTROCHEMICAL ENGINEERING	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: This course introduces to students the basic concepts of electrochemistry. This course will provide knowledge about electrochemical processes, kinetics and various electroanalytical techniques. It also outlines the applications of electrochemical engineering.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Explain the principles of electrochemical processes and concept of electrical double layer
CO2	Describe the mass transfer phenomena in electrochemical systems.
CO3	Classify the electro-analytical techniques and outline principles of electrochemical process.
CO4	Explain the principles of corrosion and basic concepts of battery.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2										
CO2	3	3										
CO3	3	2					2					
CO4	3	2					2					2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyze			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structue [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration

100	40	60	3 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Introduction to electrochemistry

Basic electrochemical thermodynamics, free energy, cell emf and Nernst equation, half-cell reactions and redox potentials.
The electrical double layer, its role in electrochemical processes, electro capillary curve, Helmholtz layer, Guoy, Stern layer.

MODULE II: Electrochemical Kinetics

Cell voltage, electrical current, overpotential and exchange current, Butler-Volmer model of electrode kinetics, Tafel plots Mass transfer in electrochemical systems: Diffusion controlled electrochemical reaction, importance of convention and the concept of limiting current, rotating disc electrode.

MODULE III: Electroanalytical techniques

Classification of electrochemical techniques: Potentiometry, Amperometry, voltammetry. Fundamental principles of cyclic voltammetry, Electrochemical Impedance spectroscopy.

MODULE IV: Electrochemical processes

Classification and understanding the principles of electrochemical process: Electro deposition, electro refining, electroforming, electro polishing, anodizing, selective solar coatings.

MODULE V: Electrochemical Engineering: Applications

Batteries: Basic concepts, battery characteristics. Lead acid battery, Lithium Ion battery. Introduction to corrosion: definition, forms of corrosion, factors and control methods of various forms of corrosion.

Text books

1. Thomas F. Fuller, John N. Harb - Electrochemical Engineering, 2018, Wiley
2. D R Crow, Principles and Applications of Electrochemistry-Chapman and Hall Chemistry Textbook Series, Springer US (1974)
3. Corrosion Engineering, Fontana M. G., McGraw-Hill, 2008, 3rd Edition

Reference books

1. Bockris J.O.M. and Reddy A.K.N, Modern Electrochemistry, Vol.1, Vol 2A and Vol 2B, Springer.
2. Bard A.J. and Faulkner L.R, Electrochemical Methods Fundamentals and Applications,

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1 (6 Hours)	
1.1	Basic electrochemical thermodynamics, free energy	1
1.2	Cell emf and Nernst equation	1
1.3	half-cell reactions and redox potentials.	1
1.4	The electrical double layer, its role in electrochemical processes, electro capillary curve	1
1.5	The electrical double layer, its role in electrochemical processes, electro capillary curve	1
1.6	Helmholtz layer, Guoy, Stern layer	1
	MODULE II (7 hours)	
2.1	Cell voltage, electrical current. overpotential and exchange current	1
2.2	overpotential and exchange current	1
2.3	Butler-Volmer model of electrode kinetics	1
2.4	Tafel plots	1
2.5	Mass transfer in electrochemical systems: Diffusion controlled electrochemical reaction.	1
2.6	Importance of convention and the concept of limiting current.	1
2.7	Rotating disc electrode.	1
	MODULE III (7 hours)	
3.1	Classification of electrochemical techniques: Potentiometry, Amperometry, voltammetry.	1

3.2	Classification of electrochemical techniques: Potentiometry, Amperometry, voltammetry.	1

3.3	Classification of electrochemical techniques: Potentiometry, Amperometry, voltammetry.	1
3.4	Fundamental principles of cyclic voltammetry,	1
3.5	Fundamental principles of cyclic voltammetry	1
3.6	Electrochemical Impedance spectroscopy.	1
3.7	Electrochemical Impedance spectroscopy	1
MODULE IV (8 hours)		
4.1	Classification and understanding the principles of electrochemical process: Electro deposition.	1
4.2	Classification and understanding the principles of electrochemical process: Electro deposition.	1
4.3	electrorefining, electroforming, electropolishing, anodizing,	1
4.4	Electropolishing, anodizing	1
4.5	Electropolishing, anodizing	1
4.6	Electropolishing, anodizing	1
4.7	selective solar coatings	1
4.8	selective solar coatings	1
MODULE V (8 hours)		
5.1	Batteries: Basic concepts.	1
5.2	battery characteristics.	1
5.3	Lead acid battery.	1
5.3	Lithium-Ion battery.	1
5.4	Introduction to corrosion: definition. forms of corrosion, factors and control methods of various forms of corrosion	1
5.5	forms of corrosion.	1
5.6	factors and control methods of various forms of corrosion	1
5.7	factors and control methods of various forms of corrosion	1
5.8	factors and control methods of various forms of corrosion	1

CO Assessment Sample Questions

1	Derive the Nernst equation and explain about its applications. State faraday' laws.
2	Write a note on electrical double layer (Helmholtz and Stern Model)
3	Explain the treatment methods used for surface cleaning of metals in electroplating
4	With a neat diagram explain lead acid batteries.

24CHE763	Renewable Energy and Environment	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: This course aims at bringing the technological developments in the field of renewable energy resources. Various renewable energy sources such as such as solar, wind, tidal, geothermal, biomass and hydrogen are covered with social and environmental aspects. Students will have insight of renewable energy production from the above mentioned sources and its impact on social and environmental scenarios are discussed. This course will give an ample opportunity to analyze and optimize the performance of renewable energy systems, making them more efficient and cost-effective.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Select suitable methods and mechanism to collect solar energy and its storage for different utilities.
CO 2	Summarize the characteristics of power production from wind energy and its environmental impacts
CO 3	Explain the mechanism of energy production from tidal and geothermal sources with its social and environmental aspects.
CO 4	Describe the mechanism of bio and thermochemical conversion for energy production from biomass.
CO 5	Summarize the policies, future scope, production, storage, transportation and safety aspects of hydrogen energy resources.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	3	2				2	2					2
CO 2	3	2				2	2					2

CO 3	3	2				2	2					2
CO 4	3	2				2	2					2
CO 5	3	2				2	2					2

Assessment Pattern

Bloom's Category	**Continuous Assessment Tools**			**End Semester Examination**
	Test1	**Test 2**	**Other tools**	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	**Attendance**	**Theory [L- T]**			**Total Marks**
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Mark distribution

Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	**40**	**60**	**3 Hrs**

End Semester Examination [ESE]: Pattern

PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60

	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Principles of Renewable Energy and Solar systems (8 Hours)

Introduction and Structure: Energy conversion chain, Scientific principles of renewable energy, standards and regulations, social implications.

Solar Energy: Basics and Concepts Concentrating and Non-concentrating Solar Collectors, Thermal Energy Storage Systems and Solar Energy Utilization Methods. Photovoltaic (PV) power technology.

MODULE II: Wind Energy (7 Hours)

Wind Energy: Basics and Concepts, Characteristics and Power Generation from Wind Energy. Environmental analysis: Construction, Normal operation, Audible sound, Infrasonic sounds, Disco effect. Shadow impact, Ice throw, Natural scenery, Preservation of bird-life, Further effects on fauna, Space consumption. Offshore wind power utilization, Acceptance. Malfunction, End of operation.

MODULE III: Tidal and Geothermal Energy (7 Hours)

Introduction, Causes of tides, enhancement of tides, tidal-current/stream power, tidal range power, social and environmental aspects. Ocean and thermal energy conversion (OTEC), OTEC principles, Devices, related technologies, social, economic and environmental aspects.

Geophysics, dry rock and hot aquifer analysis, harnessing geothermal resources, ground-source heat pumps, social and environmental aspects.

MODULE IV: Biomass Energy and Conversion (7 Hours)

Biomass, Broad Classifications, Compositions, Characteristics, Properties, Structural Components, Biomass Residues.

Utilization through Conversion Routes: Biochemical and ThermoChemical, Bioconversion into Biogas, Mechanism.

Bioconversion of Substrates into Alcohols, Thermo Chemical Conversion of Biomass, Conversion to Solid, Liquid and Gaseous Fuels-Pyrolysis, Gasification, Combustion, Chemical Conversion Processes.

MODULE V: Hydrogen Energy Technology (7 Hours)

Need for Hydrogen Energy: Global energy picture, Present and Projected Uses for Hydrogen, Prospects, Prognosis and Future for Hydrogen energy, challenges. Production of Hydrogen: from Fossil fuels, synthetic fuels. Electrolysis of water, Electrolyzers. Using Solar energy: Photochemical, Photo-catalytic, the water oxidation in nature. Fuel cell systems, basic principles and classification; proton exchange membrane fuel cell, fuel cell poisoning. Reversible and irreversible losses, efficiency of FC. application of fuel cells to automotive sectors. Case study/project. Distribution and Bulk Storage of Gaseous, Dewars for transport applications Gas Cylinders, Pipelines, Large-scale Storage. Safety regulations: Codes and Standards -Physiological, physical and chemical hazards of hydrogen, Safety of hydrogen storage facilities.
Text books 1. Twidell, J. and Tony W., Renewable Energy Resources, 2nd Edition, Taylor & Francis 2006. 2. Khan B. H., Non-Conventional Energy Resources, 2nd Edition, Tata McGraw-Hill Education Pvt. Ltd. 2009. 3. Prabir Basu, Biomass Gasification, Pyrolysis and Torrefaction, Academic Press, Elsevier, 2013. 4. Angelo Basile, Adolfo Iulianelli (Editors), Advances in hydrogen production, storage and distribution, ISBN 978-0-85709-768-2, 2014 Elsevier Ltd. 5. Broom, Darren P, Hydrogen Storage Materials: The Characterisation of Their Storage Properties, 2011, ISBN 978-0-85729-221-6, Springer.

6. Arno A. Evers, 2010. The Hydrogen Society. Hydrogeit Verlag. ISBN 978-3-937863-31-3.
Reference books 1. Martin Kaltschmitt, Wolfgang Streicher, Andreas Wiese, Renewable Energy- Technology, Economics and Environment, Springer, 2007. 2. Sukhatme S. P., Nayak J. K., Solar Energy: Principles of thermal Collection and Storage, 3rd Ed., Tata McGraw-Hill Education Pvt. Ltd 2008. 3. Fotis Rigas and Paul Amyotte, Hydrogen Safety, CRC Press, ISBN 978-1-4398-6231-5.

COURSE CONTENTS AND LECTURE SCHEDULE		
No.		**No. of Hours**
	MODULE 1	
1.1	Introduction and Structure: Energy conversion chain	1

1.2	Scientific principles of renewable energy, standards and regulations, social implications.	1
1.3	Solar Energy: Basics and Concepts	1
1.4	Concentrating Solar Collectors	1
1.5	Non-concentrating Solar Collectors	1
1.6	Thermal Energy Storage Systems	1
1.7	Solar Energy Utilization Methods	1
1.8	Photovoltaic (PV) power technology.	1
	MODULE II	
2.1	Wind Energy: Basics and Concepts	1
2.2	Characteristics	1
2.3	Power Generation from Wind Energy	1
2.4	Environmental analysis: Construction, Normal operation, Audible sound, Infrasonic sounds, Disco effect.	1
2.5	Shadow impact, Ice throw, Natural scenery, Preservation of bird-life, Further effects on fauna, Space consumption.	1
2.6	Offshore wind power utilization, Acceptance.	1
2.7	Malfunction, End of operation.	1
	MODULE III	
3.1	Introduction, Causes of tides, enhancement of tides	1
3.2	tidal-current/stream power, tidal range power, social and environmental aspects	1
3.3	Ocean and thermal energy conversion (OTEC), OTEC principles, Devices	1
3.4	related technologies,social, economic and environmental aspects	1
3.5	Geophysics, dry rock and hot aquifer analysis	1
3.6	harnessing geothermal resources, ground-source heat pumps	1
3.7	Social and environmental aspects.	1
	MODULE IV	
4.1	Biomass, Broad Classifications, Compositions, Characteristics,Properties, Structural Components, Biomass Residues.	1
4.2	Utilization through Conversion Routes: Biochemical conversion, Thermo Chemical conversion.	1
4.3	Bioconversion into Biogas: Mechanism,	1
4.4	Bioconversion of Substrates into Alcohols	1

4.5	Thermo Chemical Conversion of Biomass	1
4.6	Conversion to Solid, Liquid and Gaseous Fuels: Pyrolysis, Gasification	1
4.7	Combustion: Chemical Conversion Processes	1
	MODULE V	
5.1	Need for Hydrogen Energy: Global energy picture, Present and Projected Uses for Hydrogen, Prospects, Prognosis and Future for Hydrogen energy, challenges.	1
5.2	Production of Hydrogen: from Fossil fuels, synthetic fuels.Electrolysis of water, Electrolyzers.	1
5.3	Using Solar energy: Water Splitting with SolarEnergy, Photovoltaic Cells, Solar ThermalProcess, Photo-electrochemical Cells	1
5.4	Fuel cell systems, basic principles and classification; proton exchange membrane fuel cell, fuel cell poisoning.	1
5.5	Reversible and irreversible losses, efficiency of FC. Application of fuel cells to automotive sectors. Case study/project.	1
5.6	Distribution and Bulk Storage of Gaseous, Dewars for transport applications Gas Cylinders, Pipelines, Large-scale Storage.	1
5.7	Safety regulations. Codes and Standards - Physiological, physical and chemical hazards of hydrogen, Safety of hydrogen storage facilities.	1

	CO Assessment Sample Questions
1	Describe the working of non-concentrating solar collector for energy recovery
2	Describe the factors affecting the power generation from wind turbines.
3	If both tidal-current and tidal-range power plant are connected into a utility electricity network, is the joint power more or less variable? Explain.
4	Write the mechanism of biogas production with necessary reaction steps.
	Explain single stage and two stage anaerobic digestion systems.
5	With a neat sketch, explain the working principle of a proton exchange membrane fuel cell for hydrogen energy. Describe the operational challenges in PEM fuel cells.

24CHE773	Minerals & Metal Processing Industries	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: The course on Mineral and Metal Processing Industries is designed to provide students with a comprehensive understanding of the fundamental principles and advanced technologies employed in the extraction and processing of minerals and metals, covering a broad spectrum of topics; the course covers the definition and scope of mineral processing, separation techniques, hydrometallurgical processes, mineral properties, environmental aspects, and innovations in mineral processing technology.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Explain the role of mineral processing in the chemical engineering industry, and describe the properties of minerals.
CO 2	Identify and explain separation techniques relevant to Mineral and Metal Processing Industries.
CO 3	Explain the Hydrometallurgical Processes and their application in mineral and metal processing industries.
CO 4	Apply knowledge of sustainable mining practices, water management and energy efficiency in mineral and metal processing; explore green technologies, eco-friendly processing methods.
CO 5	Explain the innovations in tailings management, recognizing opportunities and challenges in adopting sustainable approaches.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	1					2	2	2				3
CO 2	3	2		1								3
CO 3	2	2		2								3
CO 4	2					2	1	1				3
CO 5	2					3	1	1				3

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	**Attendance**	**Theory [L- T]**			**Total Marks**
		Assignment	**Test-1**	**Test-2**	
3-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	**40**	**60**	**3 hrs**

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Overview of Mineral Processing

Overview of mineral and metal Processing: Definition and scope of mineral processing and metal processing, Role of mineral and metal processing in the chemical engineering industry, Definition of Mineral, crystalline and amorphous states, Properties depending upon light: Opalescence, Fluorescence. Ore Types and Characteristics, Classification of ores, Physical and chemical properties of ores, Principles of crushing and grinding Types of crushers and mills.

MODULE II: Separation techniques

Separation techniques: Gravity Concentration- Principles of gravity concentration, Types of gravity concentrators: Jigging, shaking tables. Magnetic Separation- Principles of magnetic separation, Magnetic and electrical separation techniques, Froth Flotation- Principles of flotation, Flotation reagents and their classification, Types of flotation cells. Introduction to ore sorting techniques. Benefits and applications of ore sorting in processing.

MODULE III: Hydrometallurgical Processes and Mineral properties
Leaching and Extraction Processes-Principles of leaching, Extraction methods: solvent extraction, ion exchange, Precipitation and Cementation- Principles of precipitation, Cementation processes, Mineral properties- Properties depending upon cohesion and elasticity: Hardness and Tenacity. Properties depending upon electricity: thermoelectricity, Pyroelectricity and Piezoelectricity. Properties depending upon Heat and Magnetism: Fusibility, Thermal conductivity, Specific heat, Para and Diamagnetism.
MODULE IV: Environmental Aspects
Sustainable Mining Practices-Overview of sustainable mining principles, Best practices for minimizing environmental impact, Case studies on successful implementation of sustainable mining practices. Energy Efficiency in Mineral Processing, Energy consumption in various mineral processing stages, Innovative technologies for energy-efficient processing, Economic and environmental benefits of energy conservation.
MODULE V: Innovations in Mineral Processing Technology
Green Technologies and Eco-Friendly Practices- Exploration of environmentally friendly processing methods, Green reagents and sustainable chemical processes, Tailings Management and Reprocessing- Innovations in tailings storage and disposal, Opportunities and challenges in tailings reprocessing, Sustainable approaches to minimize environmental impact.

Text books
1. H.H. Read - Rutley's Elements of Mineralogy 2. M.H.Battey - Mineralogy For students 3. E.S.Dana & W.E.Ford - A Text Book of Mineralogy 4. C.S.Hurlbut Dana's - Manual of Mineralogy. 5. William E. Ford Dana's - Textbook of Mineralogy 6. Pramod O Alexander - A Hand Book of Minerals, Crystals, Rocks and Ores 7. C. Hammond, The Basics of Crystallography and Diffraction, Oxford University Press, 200 8. Dutrizac, J. E. (2009). Extractive Metallurgy of Copper. Elsevier.
Reference books
1. Wills, B. A., & Finch, J. (2015). Wills' Mineral Processing Technology. Butterworth-Heinemann. 2. Fuerstenau, M. C., & Han, K. N. (2003). Principles of Mineral Processing. SME. 3. Taggart, A. F. (1945). Handbook of Mineral Dressing. Wiley. 4. Marsden, J. O., & House, C. I. (2009). The Chemistry of Gold Extraction. SME. 5. Schlesinger, M. E. (2011). Extractive Metallurgy of Copper. Elsevier. 6. Chryssoulis, S. L., & McMullen, J. (2016). Advances in Gold Ore Processing. Elsevier. 7. Wills, B. A., & Napier-Munn, T. (2006). Mineral Processing Technology. Elsevier. 8. King, R. P. (2002). Modeling and Simulation of Mineral Processing Systems. Butterworth-Heinemann.

COURSE CONTENTS AND LECTURE SCHEDULE		
No.		**No. of Hours**
	MODULE 1 (7 hours)	
1.1	Overview of mineral and metal processing: Definition and scope of mineral and metal processing.	1
1.2	Role of mineral and metal processing in the chemical engineering industry.	1
1.3	Definition of Mineral, crystalline and amorphous states, Properties depending upon light: Opalescence, Fluorescence.	1
1.4	Definition of Mineral, crystalline and amorphous states, Properties depending upon light: Opalescence, Fluorescence.	1

1.5	Ore Types and Characteristics, Classification of ores, Physical and chemical properties of ores.	1
1.6	Principles of crushing and grinding -Types of crushers and mills.	1
1.7	Principles of crushing and grinding -Types of crushers and mills.	1
MODULE II (7 hours)		
2.1	Separation techniques: Gravity Concentration- Principles of gravity concentration.	1
2.2	Types of gravity concentrators: Jigging, shaking tables.	1
2.3	Magnetic Separation- Principles of magnetic separation.	1
2.4	Magnetic and electrical separation techniques.	1
2.5	Froth Flotation- Principles of flotation, Flotation reagents and their classification.	1
2.6	Types of flotation cells. Introduction to ore sorting techniques.	1
2.7	Benefits and applications of ore sorting in processing.	1
MODULE III (8 hours)		
3.1	Leaching and Extraction Processes-Principles of leaching.	1
3.2	Extraction methods: solvent extraction, ion exchange.	1
3.3	Precipitation and Cementation- Principles of precipitation, Cementation processes.	1
3.4	Mineral properties- Properties depending upon cohesion and elasticity: Hardness and Tenacity.	1
3.5	Properties depending upon electricity thermoelectricity, Pyroelectricity and Piezoelectricity	1
3.6	Properties depending upon electricity: thermoelectricity, Pyro electricity and Piezoelectricity.	1

3.7	Properties depending upon Heat and Magnetism: Thermal conductivity, Specific heat, Para and Diamagnetism.	1
3.8	Properties depending upon Heat and Magnetism: Thermal conductivity, Specific heat, Para and Diamagnetism.	1

MODULE IV (7 hours)		
4.1	Sustainable Mining Practices-Overview of sustainable mining principles.	1
4.2	Best practices for minimizing environmental impact.	1
4.3	Best practices for minimizing environmental impact.	1
4.4	Case studies on successful implementation of sustainable mining practices.	1
4.5	Case studies on successful implementation of sustainable mining practices.	1
4.6	Energy Efficiency in Mineral Processing, Energy consumption in various mineral processing stages.	1
4.7	Innovative technologies for energy-efficient processing, Economic and environmental benefits of energy conservation.	1
MODULE V (7 hours)		
5.1	Green Technologies and Eco-Friendly Practices-Exploration of environmentally friendly processing methods.	1
5.2	Green Technologies and Eco-Friendly Practices-Exploration of environmentally friendly processing methods.	1
5.3	Green reagents and sustainable chemical processes.	1
5.4	Green reagents and sustainable chemical processes.	1
5.5	Tailings Management and Reprocessing-Innovations in tailings storage and disposal.	1
5.6	Opportunities and challenges in tailings reprocessing.	1
5.7	Sustainable approaches to minimize environmental impact.	1

CO Assessment Sample Questions	
1	How would you apply the principles of mineral processing to optimize the extraction of a specific mineral, considering its properties and industrial applications?
2	A mining operation needs to process a heterogeneous ore with varying particle sizes. Describe how gravity concentration, froth flotation, and ore sorting can be combined to achieve efficient separation. Provide specific examples of equipment and processes.
3	An ore contains a valuable metal that is challenging to extract using traditional methods. Explain how you would apply hydrometallurgical processes, such as leaching and extraction

	methods, to maximize metal recovery while minimizing environmental impact.

4	A mineral processing company aims to reduce its environmental footprint. Propose a comprehensive plan that incorporates energy conservation.
5	A mining industry is exploring options for tailings management to enhance both safety and sustainability. Recommend innovative technologies or practices for tailings disposal and reprocessing, highlighting the advantages and potential challenges associated with each

24CHE783	FOOD TECHNOLOGY	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: Food processing is a crucial aspect of the food industry, involving various unit operations and preservation techniques. This course provides a comprehensive understanding of global and Indian food scenarios, focusing on key players, trends, and techniques for different food sources. It also explores the application of these techniques in real-world, highlighting the importance of quality control and assurance in food processing. The course also covers the application of modern equipment and technology in the food industry, ensuring students gain a comprehensive skill set for diverse roles within the dynamic field.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Explain the importance of food quality, nutritive aspects, food additives and standards.
CO 2	Describe the various food processing and packing methods.
CO 3	Select suitable food preservation techniques.
CO 4	Explain the production and utilization of food products from diary, meat, poultry and fish industries.
CO 5	Describe treatment and disposal of food processing wastes.

CO - PO MAPPING

CO	PO1	PO 2	PO3	PO 4	PO5	PO6	PO 7	PO8	PO 9	PO10	PO11	PO12
CO 1	3	2				2	1					
CO 2	3	2				2	1					
CO 3	3	2				2	1					
CO 4	3	2				2	1					
CO 5	3	2				2	1					

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔

Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	**40**	**60**	**3 hr**

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I : General aspects, food constituents, food additives and food deterioration

General aspects of food industry, World and Indian food needs, Various food constituents and additives, Food deteriorative factors and their control.

MODULE II : Food processing

Preliminary processing methods. Unit operations in Food Processing. Food conversion techniques and equipment used. Food quality control, safety and regulations. and nutritive aspects.

MODULE III : Food preservation and packing techniques

Preservation by heat and cold dehydration-freezing and refrigeration, Irradiation and microwave heating, concentration, frying, sterilization and pasteurization, emerging non thermal methods of food preservation, chemicals, fermentation and pickling, hurdle technology, food canning technology-heat sterilization of canned food, canning procedures for fruits, vegetables, meats, poultry and marine products; Separation processes in food processing; food packaging, product shelf-life.

MODULE IV : Cereals, pulses, vegetables, fats and oils

Production and processing of cereals, pulses, Production and processing of vegetables, spices fats and oils

MODULE V : Food Industries and safe disposal of wastes

Food industries - Dairy products, meat, poultry and fish products, Beverage Industry- Soft and Alcoholic. Treatment and disposal of food processing wastes

Text books

1. B.Sivasankar, Food Processing and Preservation, PHI Learning Pvt. Ltd.
2. Badger, W.L, Banchero, J.T., Introduction to Chemical Engineering, McGraw Hill.
3. Food Industry Wastes: Disposal and Recovery; Herzka A & Booth RG; 1981, Applied Science Pub Ltd.
4. Hall C.W, Farall A.W & Rippen A.L, Encyclopedia of Food Engineering, Van Nostrand, Reinhold, New York.

Reference books

5. Heid J.L & Joslyn M.A, Fundamentals of Food Processing Operations, AVI Pub.
6. Unit Operations of Chemical Engineering: McCabe, Smith & Harriot, TMH, 5th edition.
7. V. Sathe, A First Course in Food Analysis, New Age International Pvt. Ltd. 1999.
8. Waston E.L., Elements of Food Engineering, Van Nostrand, Reinhold, New York.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1	
1.1	Introduction, general aspects, World and Indian food needs	1
1.2	Classes of nutrients: Carbohydrates, Fats	1
1.3	Classes of nutrients: Proteins Minerals	1
1.4	Classes of nutrients: Vitamins, Water	1
1.5	Additives: Preservatives, Nutritional additives, Flavouring agents, Colouring agents, Texturizing agents, Miscellaneous additives	1
1.6	Food deteriorative factors and their control	1
	MODULE II	
2.1	Preliminary processing methods: cleaning, sorting and grading methods	1
2.2	Unit operations in Food Processing.	1
2.3	Food conversion techniques and equipment used: size reduction and screening of solids, mixing.	1
2.4	Food conversion techniques and equipmentused: Emulsification, filtration.	1
2.5	Food conversion techniques and equipment used: membrane separation, centrifugation.	1
2.6	Food conversion techniques and equipment used: extraction and crystallisation.	1
2.7	Food quality control and nutritive aspects: sensory evaluation of food quality and regulation, quality factors for consumer safety.	1

MODULE III		
3.1	Introduction to thermal destruction kineticsof microorganisms.	1
3.2	Thermal process time for sterilisation, heat sterilization of canned food, factors affecting thermal process time.	1
3.3	Hot and cold preservation techniques:Sterilization, pasteurization and blanching	1
3.4	Chemicals, fermentation and pickling, hurdle technology	1
3.5	Food canning technology- canning procedures for fruits,	1
3.6	Food canning technology- vegetables, meats, poultry and marine products	1
3.7	Separation processes in food processing; Packing methods.	1
MODULE IV		
4.1	Production and processing of rice, manufacture of parched rice, puffed rice and flaked rice.	1
4.2	Production and processing of wheat, manufacture of bread.	1
4.3	Pulse processing: methods to improve nutritive aspects of pulses	1
4.4	Production of fats and oils: rendering, pressing, solvent extraction.	1
4.5	Refining of edible oil, hydrogenation and interesterification.	1
4.6	Harvesting and processing of vegetables.	1
4.7	Harvesting and processing of spices.	1
MODULE V		
5.1	Dairy industry: milk processing, dairy products: manufacture of butter	1
5.2	Dairy products: manufacture of Cheese, ice cream	1
5.3	Meat, poultry and fish products	1
5.4	Preservation techniques for meat, poultry and fish products	1
5.5	Beverage Industry- Soft drinks, their classification	1

5.6	Alcoholic beverages: malted beverage, manufacture of beer, manufacture of fermented beverages: wine and cider	1
5.7	Manufacture of distilled beverages: Brandy	1
5.8	Treatment and disposal of food processing wastes	1

CO Assessment Questions	
1	Enumerate and explain food nutrients.
2	Explain the wet cleaning methods in the food industry.
3	List out and explain the different factors that influence the thermal destruction kinetics of the microorganisms in the heat treatment of food materials.
4	With a neat flow sheet explain the steps involved in milk processing.
5	Describe the safe disposal of wastes from a food industry.

24CHE793	DRUGS AND PHARMACEUTICALS TECHNOLOGY	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: This course focuses on understanding the development of drugs and therapeutic agents. This includes various unit processes, preformulation, formulation techniques for conventional drug development and sterilization techniques. The course helps the student to understand the different dosage forms, purity and effectiveness of the drugs developed.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Explain principles of preformulation and basic formulation considerations for monophasic liquid orals and emulsions suspensions, and aerosols.
CO2	Describe preformulation, formulation and unit operation involved in the manufacturing of tablets.
CO3	Explain dosage forms, principles and quality control.
CO4	Describe formulations for hard and soft gelatin capsules, machinery used for filling hard gelatin capsules, process for soft gelatin capsules manufacturing, evaluation of capsules.
CO5	Describe preformulation, formulation, evaluation and large-scale manufacturing, packaging of oral controlled release and sustained release products.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2										
CO2	3	2										
CO3	3	2										
CO4	3	2										
CO5	3	2										

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	

3-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 hours
End Semester Examination [ESE]: Pattern			
PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS
MODULE I: Introduction to pharmaceutical industry
Pharmaceutical Industry, Drug discovery and Development of Drugs, Organic Therapeutic agents uses and Economics. Chemical Conversion Processes (Restricted to brief explanation for assessment)- Alkylation, Carboxylation, Condensation, Cyclisation, Dehydration, Esterification, Halogenation Oxidation, Sulfonation, Complex Chemical Conversions and Fermentation. Preparation, properties, uses and testing of the following pharmaceuticals and fine chemicals, sulfacetamide, paracetamol, methyl orange, riboflavin, nicotinamide, procaine hydrochloride, para-amino salicylic acid, isonicotinic acid hydrazide, aspirin, penicillin, calcium gluconate, ferric ammonium citrate (preparation study of all the listed polymers are required).
MODULE II: Tablets and Capsules

Compressed Tablets, Wet Granulation, Dry Granulation or Slugging, Direct Compression, Tablet Presses, Formulation, Introduction to tablet coating: rationale, advantages etc. Preformulation considerations for tablet coating, Types of coating, Quality control of coated and uncoated tablets, Introduction to capsule dosage form: rationale, advantages. Preformulation considerations for capsule dosage form. Hard gelatin capsules: formulation considerations, capsule manufacture equipments, quality control tests, packaging, Soft gelatin capsules: formulation considerations, capsule filling equipments, quality control tests, packaging.
MODULE III: Monophasics, Biphasic and Emulsions
Monophasics (Oral and Topicals) (solution, syrups, elixirs, linctus, nasal drops, ear drops, etc.), preformulation, Formulation, Quality Control. Biphasic – Suspensions, preformulation, Principles and Stabilization techniques, Formulation Development,

Evaluation, Large scale manufacture and packaging with focus on equipment. Biphasic – Emulsions, preformulation, theories of emulsions, formulation, Evaluation including stress testing, Large scale manufacture and packaging with focus one equipment Parenteral preparations: large volume and small volume parenterals, Standard of Hygiene and Good Manufacturing Practice (GMP), Packing techniques and quality control.
MODULE IV: Ointments, Creams, Gels and Aerosols
Ointments- Preformulation, Formulation, Evaluation, Large scale manufacture and packaging with focus on equipment. Creams & Gels- Preformulation, Formulation, Evaluation, Large scale manufacture and packaging with focus on equipment. Aerosols- Containers and Propellants, Formulation of aerosols, Evaluation of aerosols Oral sustained release and controlled release formulations, Preformulation, Formulation of matrix and reservoir type systems, Drug targeting: concepts, liposomes, nanoparticles, niosomes.
MODULE V: Sterilization and Analytical Methods
Sterilization: Introduction, risk factor, methods of sterilization, heat (dry and moist), heating with bactericide, filtration, gaseous sterilization and radiation sterilization, suitable example to be discussed and sterilization testing. Analytical Methods and Tests for various Drugs & Pharmaceuticals- principle, instrumentation and applications of UV/VIS and IR spectroscopy, X-ray diffraction analysis, Fourier transform spectroscopy, chromatography principle and its types, fluorimetry, polarimetry.
Text books 1. Shayne Cox Gad. Pharmaceutical Manufacturing Handbook, Published by John Wiley and Sons, Inc., 2008. 2. Bernd Meibohm. Pharmacokinetics and Pharmacodynamics of biotech drugs, Published by Wiley-VCH, 2006. 3. Rawlines, E.A.; “Bentleys Text book of Pharmaceutics “, III Edition, Bailliere

Tindall, London, 1977.

Reference books

1. Remington-The Science and Practice of Pharmacy (Vol.1& 2).
2. Pharmaceutical Production Facilities: Design & Applications, Graham C. Cole,1st Edition, 1990, Ellis Horwood.
3. Theory & Practice of Industrial Pharmacy, Leon Lachman, Herbert A. Lieberman & Joseph Kanig, 3rdedition, 1987, Lea & Febiger, Philadelphia.
4. ICH Guidelines 7 Coated Pharmaceutical Dosage Forms, K. H. Bauer, CRC Press, Boca Raton. Med Pharm.
5. Pharmaceutical Coating Technology, G. C. Cole, New York, Ellis, Horwood, 1990.
6. Pulsed and Self-Regulated Drug Delivery, J. Kost, Florida, CRC Press, 1987.
7. Extended Release Dosage Forms, - KlowCzynski, Florida, CRC Press, 1987
8. Hard Capsules: Development and Technology, K. Ridgway, London Pharmaceutical Press 1987.
9. Process Systems Engineering for Pharmaceutical Manufacturing Volume 41, Edited by Ravendra Singh, Zhihong Yuan Tsinghua, Elsevier, 2018.
10. Pharmaceutical Suspensions from Formulation Development to Manufacturing, Edited by Alok K. Kulshreshtha, Onkar N. Singh, G. Michael Wall, Springer, 2010.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE 1 (6 hours)		
1.1	Pharmaceutical Industry, Drug discovery and Development of Drugs, Organic Therapeutic agents uses and Economics.	1
1.2	Chemical Conversion Processes - Alkylation, Carboxylation, Condensation, Cyclisation, Dehydration.	1
1.3	Esterification, Halogenation Oxidation, Sulfonation, Complex Chemical Conversions and Fermentation.	1

1.4	Outlines of preparation, properties, uses and testing of the following pharmaceuticals and fine chemicals, sulfacetamide, paracetamol, methyl orange, riboflavin, nicotinamide.	1
1.5	Outlines of preparation, properties, uses and testing of the following pharmaceuticals and fine chemicals, procaine hydrochloride, para-amino salicylic acid, isonicotinic acid hydrazide.	1
1.6	Outlines of preparation, properties, uses and testing of the following pharmaceuticals and fine aspirin, penicillin, calcium gluconate, ferric ammonium citrate.	1
MODULE II (8 hours)		
2.1	Compressed Tablets: Formulation.	1
2.2	Wet Granulation, Dry Granulation or Slugging, Direct Compression.	1
2.3	Tablet Presses, processing problems.	1
2.4	Introduction to tablet coating: rationale, advantages Types of coating.	1
2.5	Quality control of coated and uncoated tablets.	1
2.6	Introduction to capsule dosage form. Hard gelatin capsules: formulation considerations, capsule manufacture equipments, quality control tests, packaging.	1
2.7	Soft gelatin capsules: formulation considerations, capsule filling equipments, quality control tests, packaging.	1
2.8	Microencapsulation, Fabrication techniques, Evaluation.	1

MODULE III (9 hours)		
3.1	Monophasic liquids: Oral and Topicals (solution, syrups, elixirs, linctus, nasal drops, ear drops, etc.), Formulation, Quality Control.	1
3.2	Biphasic - Suspensions Preformulation Principles and Stabilization techniques Formulation Development.	1

3.3	Biphasic - Emulsions Preformulation Theories of emulsions Formulation.	1
3.4	Evaluation including stress testing Large-scale manufacture and packaging with focus on equipment.	1
3.5	Parenteral preparations: large volume and small volume parenterals.	1
3.6	Formulation of small and large volume parenterals.	1
3.7	Standard of Hygiene and Good Manufacturing Practice (GMP).	1
3.8	Packing techniques.	1
3.9	Quality control.	1
MODULE IV (7 hours)		
4.1	Ointments Preformulation Formulation Evaluation Large scale manufacture and packaging with focus on equipment.	1
4.2	Creams Preformulation Formulation Evaluation Large scale manufacture and packaging with focus on equipment, Gels • Preformulation Formulation Evaluation Large scale manufacture and packaging with focus on equipment.	1
4.3	Suppositories Preformulation Formulation Evaluation Large scale manufacturing with focus on equipment.	1
4.4	Aerosols Containers and Propellants.	1
4.5	Formulation of aerosols Evaluation of aerosols.	1
4.6	Oral sustained release and controlled release formulations • Preformulation Formulation of matrix and reservoir type systems.	1
4.7	Drug targeting: concepts, liposomes, nanoparticles, niosomes.	1
MODULE V (5 hours)		
5.1	Sterilization: Introduction, risk factor, methods of sterilization,	1

	heat (dry and moist).	

5.2	Heating with bactericide, filtration, gaseous sterilization and radiation sterilization, suitable example to be discussed and sterilization testing.	1
5.3	Analytical Methods and Tests for various Drugs & Pharmaceuticals- principle, instrumentation and applications of UV/VIS and IR spectroscopy.	1
5.4	X-ray diffraction analysis, Fourier transform spectroscopy.	1
5.5	Chromatography principle and its types, fluorimetry, polarimetry.	1

CO Assessment Sample Questions	
1	1. Explain the methods of filling of aerosol and the evaluation of aerosol system. 2. Explain the significance of preformulation studies in manufacture of suspensions. 3. Explain theories of emulsification.
2	1. List out the steps involved for tablet compression. 2. Classify the different types of tablets. Give an account of tablet compaction by rotary compression process. 3. Explain processing problems encountered in compression of tablets.
3	1. Explain various enteric and non-enteric polymers used for tablet coating. 2. Explain the steps involved in sugar coating. 3. Explain the significance of microencapsulation and discuss any one microencapsulation technique.
4	1. Describe the manufacture of soft gelatin capsule by Rotary die process. 2. Discuss about the quality control test for hard gelatin capsules. 3. Explain the limitation for using hard gelatin capsules.
5	1. Explain the approaches involved in design of controlled release formulations. 2. Explain the concepts of drug targeting. 3. Describe the manufacture of liposomes.

SEVENTH SEMESTER

OPEN ELECTIVE-1 / INDUSTRIAL ELECTIVE

24CHI714	Process Safety and Hazard Assessment	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: In the realm of chemical processes, ensuring safety is paramount. The subject Process safety and hazard assessment aims to equip students with the knowledge and practical skills necessary to foster a culture of safety within a chemical process plant.

Prerequisite: NIL

Course Outcomes: After the completion of the course the student will be able to

CO1	Explain the basic concepts related to safety in Process Industries.
CO2	Explain the fundamental principles of fire science.
CO3	Recognize various hazards associated in chemical process industries.
CO4	Demonstrate various safety aspects of chemical plant operation
CO5	Apply suitable techniques to anticipate and quantify hazards in chemical process industries.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2				2				2		
CO2	3	2				2				2		
CO3	3					2				2		
CO4	3					2				2		
CO5	3					2				2		

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Introduction to chemical process Safety

Concept and importance of industrial safety. Definitions: Accident, Injury, Unsafe act, Unsafe Condition, Dangerous Occurrence, Reportable Accidents-Cost of accidents-Theories of accident causation- Safety Policy-Safety Officer-responsibilities, authority. Safety committee-need, types, advantages- Monitoring Safety Performance: Frequency rate, severity rate, incidence rate, activity rate Review of major Industrial accidents: Bhopal, Flixborough and SEVESO

MODULE II: Fire protection systems in chemical process industries

Elements of fire- Classes of fire- NFPA diamond- Measures of Flammability-Fire alarms: addressable and non-addressable type-Fire detectors-portable and fixed fire protection systems- Basic concept of firefighting with water, carbon dioxide, powders, foams, halons.

MODULE III: Hazards in chemical industries

Chemical hazards: Classification- Allowable concentrations: T.L.V-TWA, STEL, TLV-C, IDLH. Physical hazards-Atmospheric contaminants, Sound, Vibration Light, Radiation and Temperature. Electrical hazards, Ergonomic hazards, Chemical reaction hazards: Runaway Reaction. Specific reactive chemical hazards: Pyrophoric substances, Oxidizers, Polymerizing substances etc.

MODULE IV: Safety Practices in chemical process industries

Inherently safer design, Hazardous area classification, Work permit systems, MSDS -HAZCHEM Code, Personal protective equipments: respiratory and non-respiratory equipment-Emergency planning: onsite and offsite emergency planning, Mock drill.

MODULE V: Hazard assessment techniques

Safety Inspections, safety Audits, Dow index, HAZOP, Fault tree analysis, Failure mode and effect analysis, Event tree analysis, Bow tie diagram.

Text books

1. Daniel A Crowl& Joseph F Louvar, Chemical Process Safety, Second Edition, Prentice-Hall.
2. B. K. Bhaskara Rao, Er. R. K. Jain, Vineet Kuma, Safety in Chemical Plants/Industry and Its Management", Khanna Publishers, First edition, 2010

Reference books

1. Sam Mannan (Editor). Lee's Loss Prevention in the Process Industries. (Fourth edition). Butterworth-Heinemann Ltd., UK. (2012).
2. AIChE/CCPS. Guidelines for Chemical Process Quantitative Risk Analysis. (second edition). Centre for Chemical Process Safety, American Institute of Chemical Engineers, New York. (2000).
3. Bob Skelton. Process safety analysis: An Introduction, Institution of Chemical Engineers. (1997)
4. AIChE/CCPS. Guidelines for Hazard Evaluation Procedures. (Second edition). Centre for Chemical Process Safety, American Institute of Chemical Engineers, New York. (1992).
5. Ian T. Cameron and Reghu. Raman, Process Systems Risk Management, Volume (Process Systems Engineering) Elsevier Academic press, (2005).
6. NFPA fire protection handbook.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1 (6 hours)	
1.1	Concept and importance of industrial safety.	1
1.2	Definitions: Accident, Injury, Unsafe act, Unsafe Condition, Dangerous Occurrence, Reportable Accidents-Cost of accidents	1
1.3	Theories of accident causation	1
1.4	Safety Policy-Safety Officer-responsibilities, authority. Safety committee-need, types, advantages	1
1.5	Safety Performance: Frequency rate, severity rate, incidence rate, activity rate	1
1.6	Review of major Industrial accidents: Bhopal, Flixborough and SEVESO	1

MODULE II (7 hours)		
2.1	Elements of fire- Classes of fire- NFPA diamond	1
2.2	Measures of Flammability	1
2.3	Fire alarms: addressable and non-addressable type	1
2.4	Fire detectors	1
2.5	Portable fire protection systems	1
2.6	Fixed fire protection systems	1
2.7	Basic concept of firefighting with water, carbon dioxide, powders, foams, halons.	1
MODULE III (7 hours)		
3.1	Chemical hazards: Classification- Allowable concentrations: T.L.V-TWA, STEL, TLV-C, IDLH.	1
3.2	Physical hazards-Atmospheric contaminants, Sound, Vibration	1
3.3	Physical hazards-Light, Radiation and Temperature.	1
3.4	Electrical hazards	1
3.5	Ergonomic hazards	1
3.6	Chemical reaction hazards: Runaway Reaction	1
3.7	Specific reactive chemical hazards: Pyrophoric substances, Oxidizers, Polymerizing substances etc.	1
MODULE IV (5 hours)		
4.1	Inherently safer design, Hazardous area classification	1
4.2	Work permit systems	1
4.3	MSDS -HAZCHEM Code	1
4.4	Personal protective equipments: respiratory and non-respiratory equipment	1
4.5	Emergency planning: onsite and offsite emergency planning, Mock drill.	1
MODULE V (10 hours)		
5.1	Safety Inspections	1
5.2	Safety audit	1
5.3	Dow index	1
5.4	HAZOP	1
5.5	HAZOP	1

5.6	Fault tree analysis	1
5.7	Fault tree analysis	1
5.8	Failure mode and effect analysis	1
5.9	Event tree analysis	1
5.10	Bow tie diagram.	1

CO Assessment Questions	
1	List the various accident causation theories and explain any one in details
2	Distinguish between addressable and non-addressable type fire alarm systems.
3	Air contains 5 ppm of diethylamine (TLV-TWA of 5 ppm), 20 ppm of cyclohexanol (TLV-TWA of 50 ppm), and 10 ppm of propylene oxide (TLV-TWA of 2 ppm). Find the mixture TLV-TWA. Are the workers overexposed under these conditions?
4	Discuss the formation and uses of HAZCHEM code. Explain the code 3YE
5	Differentiate between safety audit and safety inspection. Briefly explain the audit procedure.

24CHO724	PROCESS UTILITY & PIPELINE DESIGN	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: The course focuses on understanding the important fundamentals of chemical process utilities and pipeline design. The course covers process utility systems, introduction to fuels, steam systems, refrigeration, ventilation and an overview of piping. The emphasis on the fundamentals will help the student to understand the concepts and apply them accordingly.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Describe the major types, processes and associated equipments of utility systems employed in industries.
CO2	Compute the power rating of equipments.
CO3	Perform mathematical calculations involved in steam generation, humidification and refrigeration operations.
CO4	Select the relevant pipes for various chemical processes.
CO5	Identify different types of pipes, joints, fittings and related accessories used in process plants.
CO6	Choose relevant insulation material for piping systems.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3				2						2
CO2	3	3	2									2
CO3	3	3	2									2
CO4	3	3				2						2
CO5	3	3										3
CO6	3	3										2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure	Attendance	Theory [L- T]	Total

[L-T-P-J]		Assignment	Test-1	Test-2	Marks
3-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Process Utility Systems

Process Utility Systems: Classification of process utility systems, Importance of process utilities in chemical industries and plants. Water as a utility in process industries: Sources of water, hard and soft water, requisites of industrial water and its uses, methods of water treatment, storage and distribution of water, recycle and conservation of water. Cooling Tower: Types and performance evaluation.

MODULE II: Introduction to fuels

Introduction to Fuels, Properties of Fuel oil, Coal and Gas, Storage, handling and preparation of fuels, Principles of Combustion, Combustion of Oil, Coal and Gas. Compressed air system: Types of air compressors, Compressor efficiency, Efficient compressor operation, Compressed air system components, Capacity assessment, Leakage test, Factors affecting the performance and efficiency of compressors. Vacuum Pumps: Types of vacuum pumps and their performance characteristics.

MODULE III: Steam System

Steam System: Steam and its importance, Properties of steam, Problems based on enthalpy calculation for wet steam, dry saturated steam and superheated steam. Boilers: Types of steam generators/boilers, Combustion in boilers, Performance evaluation, Analysis of losses, Feed water treatment, Blow down, Energy conservation opportunities, Boilers Act. Steam handling and distribution: Steam distribution system, Assessment of steam distribution losses, Steam economy, Steam traps, Condensate and flash steam recovery system, Identifying

opportunities for energy savings. Waste Heat Recovery: Classification, Advantages and applications, commercially viable waste heat recovery devices, Saving potential. (Can reduce the content by referring to the core course of Piping if there is any overlap)
MODULE IV: Refrigeration and Ventilation
Refrigeration and Ventilation: Principles of refrigeration, vapour compression and vapour absorption refrigeration cycles, types of refrigerants and their importance. Production of cryogenic temperatures. Characteristics of Air-water systems. Humidification and Dehumidification equipments. Exhaust & Ventilation.
MODULE V: Introduction to Piping
Introduction to Piping: Classification of pipes, pipe materials, pipe sizing, pipe wall thickness, schedule number, codes and standards. Piping colour codes as per types of fluid passing through pipes. Piping Components: Pipes, Fittings, Flanges, Gaskets, Bolting and Valves. Pipe fittings: Functions and properties, types of pipe fittings and their selection. Gaskets: Functions and properties, types of gaskets and their selection. Valves: Types of valves, selection criteria of valves for various systems. Piping insulation: Insulation materials, estimating thickness of insulation, critical thickness of insulation, optimal thickness of insulation.
Text books 1. Jack Broughton, “Process utility systems”, Institution of Chem. Engineers, U.K. 2. M.S. Peters and Timmerhaus, “Plant design and Economics for Chemical Engineers”, Mc Graw Hill, 3rd Edition. 3. Roger Hunt and Ed Bausbacher, “Process Plant layout and Piping Design” PTR Prentice Hall Inc. 4. F.C. Vibrandt and C.E. Dryden, “Chemical Engineering Plant Design”, McGraw Hill, Fifth Edition.

Reference books

1. Nordell, Eskel, Water Treatment for industrial and other uses, Reinhold Publishing Corporation, New York (1961).
2. Plant Utilities by Dr. Mujawar, Nirali Prakashan Publication.
3. Plant Utilities by D.B. Dhone, Nirali Prakashan Publication.
4. P.L.Balleney, Thermal Engineering, Khanna Publisher, New Delhi.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE I (5 hours)		
1.1	Process Utility Systems: Classification of process utility systems.	1
	Importance of process utilities in chemical industries and plants.	1
1.2	Water as a utility in process industries: Sources of water, hard and soft water, requisites of industrial water and its uses.	1
1.3	Methods of water treatment, storage and distribution of water, recycle and conservation of water.	1
1.4	Cooling Tower: Types and performance evaluation.	1
MODULE II (6 hours)		
2.1	Introduction to Fuels, Properties of Fuel oil, Coal and Gas, Storage.	1
2.2	Handling and preparation of fuels, Principles of Combustion, Combustion of Oil, Coal and Gas.	1
2.3	Compressed air system: Types of air compressors.	1
2.4	Compressor efficiency, Efficient compressor operation, Compressed air system components, Capacity assessment	1
2.5	Leakage test, Factors affecting the performance and efficiency of compressors.	1
2.6	Vacuum Pumps: Types of vacuum pumps and their performance characteristics.	1
MODULE III (8 hours)		

3.1	Steam System: Steam and its importance, Properties of steam, Problems based on enthalpy calculation for wet steam, dry saturated steam and superheated steam.	1
3.2	Boilers: Types of steam generators/boilers.	1
3.3	Combustion in boilers, Performance evaluation, Analysis of losses, Feed water treatment.	1
3.4	Blow down, Energy conservation opportunities, Boilers Act.	1
3.5	Steam handling and distribution: Steam distribution system, Assessment of steam distribution losses.	1
3.6	Steam economy, Steam traps, Condensate and flash steam recovery system, Identifying opportunities for energy savings.	1
3.7	Waste Heat Recovery: Classification, Advantages and applications.	1
3.8	Commercially viable waste heat recovery devices, Saving potential.	1
MODULE IV (6 hours)		
4.1	Refrigeration and Ventilation: Principles of refrigeration, vapour compression.	1
4.2	Vapour absorption refrigeration cycles.	1
4.3	Types of refrigerants and their importance. Production of cryogenic temperatures.	1
4.4	Characteristics of Air-water systems.	1
4.5	Humidification and Dehumidification equipments.	1
4.6	Exhaust & Ventilation.	1
MODULE V (10 hours)		
5.1	Introduction to Piping: Classification of pipes, pipe materials, pipe sizing, pipe wall thickness, schedule number, codes and standards.	1

5.2	Piping colour codes as per types of fluid passing through pipes.	1
5.3	Piping Components: Pipes, Fittings, Flanges, Gaskets, Bolting and Valves.	1
5.4	Pipe fittings: Functions and properties.	1
5.5	Types of pipe fittings and their selection.	1
5.6	Gaskets: Functions and properties, types of gaskets and their selection.	1
5.7	Valves: Types of valves.	1
5.8	Selection criteria of valves for various systems.	1
5.9	Piping insulation: Insulation materials, estimating thickness of insulation.	1
5.10	Critical thickness of insulation, optimal thickness of insulation.	1

CO Assessment Sample Questions	
1	1. State and explain any seven requirements of a good water distribution system. 2. Differentiate primary and secondary plant utility systems.
2	1. Classify different types of vacuum pumps and explain performance characteristics. 2. A single stage compressor is used to compress 800 m^3/hr of CO2 measured at 288 K and 1 bar from its initial stage of 0.5 bar and 300 K to a final pressure of 1.5 bars. A volumetric efficiency of 75 % and a compression efficiency of 85 % may be assumed. Assuming adiabatic compression, calculate the power required for driving the compressor, the piston displacement in m^3/s and the discharge temperature.
3	1. Define Psychrometry? Enumerate and explain different psychrometric processes and represent them on a psychrometric chart. 2. Distinguish economy and capacity with respect to boilers? List and explain the different types of boilers used in chemical industry. 3. A refrigeration system has working temperature of –27°C and 37°C. Find

	out actual COP, if it is 70% of Maximum.
4	1. State and explain some of the general considerations that should be evaluated when selecting and applying materials for piping. 2. Explain an equivalent pipe. Write the expression for equivalent size of a compound pipe.
5	1. Explain the effect of pipe fitting on pressure losses. 2. Give the significance of hangers and supports in pipeline design. List different types of pipe hangers and pipe supports.
6	1. Classify different insulation materials based on the application in commercial piping industry. 2. Explain economic thickness of insulation. List any two parameters required to evaluate economic thickness of insulation.

SEVENTH SEMESTER HONOUR

24CHH709	PROCESS INTEGRATION AND INTENSIFICATION	L	T	P	J	S	C	Year of Introduction
		4	0	0	0	4	4	2024

Preamble: The objective of this course is to impart the knowledge of systematic methods for the material and energy integration of chemical process industries. In this course, particular emphasis will be given to various techniques for process integration and intensification of heat exchangers, mass exchangers, reactors and distillation columns.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Optimize the heating and cooling utility requirement
CO2	Design heat exchanger network using pinch technology
CO3	Modify processes for minimization of raw material and waste generation.
CO4	Demonstrate a comprehensive understanding of process intensification principles
CO5	Explain the types of process intensification techniques

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3									
CO2	3		3								2	
CO3	3		3									
CO4	3		3									
CO5	3		3									

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	√	√	√	√
Understand	√	√	√	√
Apply	√	√	√	√
Analyse			√	
Evaluate			√	
Create			√	

Mark Distribution of CIA

		Theory [L- T]	

Course Structure [L-T-P-J]	Attendance	Assignment	Test-1	Test-2	Total Marks
4-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Process Integration (11 hours)

Definition of Process Integration, Areas of application and techniques available for Process Integration, Onion model of chemical process design, Role of thermodynamic laws. Energy targeting methods of Heat Exchanger Networks: Composite curve method,
Problem table algorithm, Grand composite curve.

MODULE II: Targeting of Heat Exchanger Network (9 hours)

Number of units targeting, Area targeting, Cost targeting, Number of shells targeting.
Heat Exchanger Network Design: The pinch design method, Grid diagram, Stream splitting design for single pinch networks.

MODULE III: Mass Exchanger Network Synthesis (11 hours)

Mass Exchanger Network, Minimum Mass Separating Agents (MSA), Mass exchange
networks for minimum external MSA. Water system design: Water use, Targeting maximum water reuse for single contaminants.

MODULE IV : Mechanism involved in the process intensification (8 hours)

Intensification by fluid flow process, Mechanism of Intensification by mixing, Intensification in Reactive system.Problems leading to sustainable development Concept, Issues and Challenges, Strategies in process design.Scales and stages of process intensification, Methods and Tools for Achieving sustainable design,Multi-level
Computer aided tools.

MODULE V: Types and features of process intensification (9 hours)

Stochastic Optimization, Optimization Algorithms, Applications of Optimization
Algorithms.Mechanism of Cavitation-based PI, Cavitational Reactor Configurations
and activity, Parametric effects on cavitation. Principles, Types of Intensified
Distillation Units, Design of membrane-assisted distillation.

Text books

1. Robin Smith, Chemical Process Design and Integration, John Wiley and Sons. Ltd., New Delhi,2005.
2. 2. Uday. V. Shenoy, Heat Exchanger Network Synthesis, Gulf Publishing Co, USA, 1995.
3. Andrzej Stankiewicz, Tom Van Gerven, Georgios Stefanidis,The Fundamentals of Process Intensification ,John Wiley & Sons Technology & Engineering, 2019.

Reference books

1. Warren D. Seider, J. D. Seader and Daniel R. Lewin, Product & Process Design Principles, Wiley Publication.
2. James M. Douglas, Conceptual Design of Chemical Process, McGraw Hill, New York, 1988.
3. Kemp I.C, Pinch Analysis and Process Integration - A user guide on process integration for efficient use of energy, 2nd Edition, Butterworth – Heinneman, 2006.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE I	
1.1	Process Integration: Definition of Process Integration, Areas of application and techniques available for Process Integration.	1
1.2	Onion model of chemical process design, Role of thermodynamic laws.	1

1.3	Energy targeting methods of Heat Exchanger Networks: Hot Composite curve	1
1.4	Energy targeting methods of Heat Exchanger Networks: Hot Composite curve	1
1.6	Cold composite curve	1
1.7	Pinch determination	1
1.8	Pinch determination	1
1.9	Problem table algorithm	1
1.10	Problem table algorithm	1
1.11	Grand composite curve	1
	MODULE II	
2.1	Targeting of Heat Exchanger Network: Area targeting	1
2.2	Targeting of Heat Exchanger Network: Area targeting	1
2.3	Targeting of Heat Exchanger Network: Area targeting	1
2.4	Number of units targeting, Cost targeting, Number of shells targeting.	1
2.5	Number of units targeting, Cost targeting, Number of shells targeting.	1
2.6	Heat Exchanger Network Design: The pinch design method	1
2.7	Grid diagram, Stream splitting design for single pinch networks.	1
2.8	Grid diagram, Stream splitting design for single pinch networks.	1
2.9	Grid diagram, Stream splitting design for single pinch networks.	1
	MODULE III	
3.1	Mass Exchanger Network Synthesis: Mass Exchanger Network	1
3.2	Minimum Mass Separating Agents (MSA): Concentration interval method	1
3.3	Minimum Mass Separating Agents (MSA): Concentration interval method	1
3.4	Composite curve method	1
3.5	Composite curve method	1
3.6	Mass exchange networks for minimum external MSA	1

3.8	Mass exchange networks for minimum external MSA	1
3.9	Water system design: Water use	1
3.10	Targeting maximum water reuse for single contaminants.	1
3.11	Targeting maximum water reuse for single contaminants.	1
	MODULE IV	
4.1	Intensification by fluid flow process	1
4.2	Mechanism of Intensification by mixing, Intensification in Reactive system	1
4.3	Mechanism of Intensification by mixing, Intensification in Reactive system	1
4.4	Problems leading to sustainable development Concept, Issues and Challenges	1
4.5	Problems leading to sustainable development Concept, Issues and Challenges	1
4.5	Strategies in process design. Scales and stages of process intensification	1
4.6	Strategies in process design. Scales and stages of process intensification	1
4.7	Methods and Tools for Achieving sustainable design.	1
4.8	Multi-level Computer aided tools.	1
	MODULE V	
5.1	Stochastic Optimization, Optimization Algorithms	1
5.2	Applications of Optimization Algorithms	1
5.3	Mechanism of Cavitation-based PI	1
5.4	Cavitational Reactor Configurations and activity, Parametric effects on cavitation	1
5.5	Cavitational Reactor Configurations and activity, Parametric effects on cavitation	1
5.6	Principles, Types of Intensified Distillation Units,	1
5.7	Principles, Types of Intensified Distillation Units,	1
5.8	Design of membrane-assisted distillation.	1
5.9	Design of membrane-assisted distillation.	1

CO Assessment Sample Questions	
1	Define the term process integration.
2	Write Euler's equation and briefly explain its use in process integration.
3	List out the heuristics for mass exchanger network design.
4	Explain the intensification of reactive systems.
5	Enumerate the steps followed in the design of membrane-assisted distillation.

24CHH710	Energy Economics and Policy	L	T	P	J	S	C	Year of Introduction
		4	0	0	0	4	4	2024

Preamble: This course covers the economic principles that guide energy related behavior of both the producers and the consumers of energy and the policy regime that has emerged to govern it. The course aims at broadening the vision of students while making any energy related decision as a technology developer, energy manager, entrepreneur, policy maker, researcher in future or simply for personal energy use in day-to-day activities.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Describe Energy consumption in various sectors and Policy implemented for energy security and climate change.
CO 2	Calculate the energy cost based on generation and consumption.
CO 3	Explain the Energy Regulations and policies implemented in Indian Power Sector
CO 4	Estimate the energy tariff with respect to Central and State Regulatory Commission.
CO 5	Describe the salient features of renewable energy policies.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	3					3	3					2
CO 2	3	3				3	3					2
CO 3	3					3	3					2
CO 4	3	3				3	3					2
CO 5	3					3	3					2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
4-0-0-0	5	15	10	10	40

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 hours

<u>End Semester Examination [ESE]: Pattern</u>

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Energy and Policy (9 Hours)

Introduction, sector wise consumption of energy resources: Electricity, Fuel, Transportation, Energy Scenario of different sectors: Indian and International Level – Coal, Oil, Natural Gas, RE, Hydro, Nuclear. Global market outlook, import and export position, Resources, Reserves, All India Energy Scenario, Energy Conservation Act 2001 and amendments, Energy Security -Concept, Issues and Economics, Trade-Off between Energy Security and Climate Change.
MODULE II: Energy Economics (9 Hours)
Time Value of Money Concept, Simple Payback Period, IRR, NPV, Life Cycle Costing, LCA, LCOE, Cost of Saved Energy, Cost of Energy generated, Examples from energy generation and conservation, Energy Chain.
MODULE III: Energy Regulations in Indian Power Sector (9 Hours)
Structure of Indian Power Sector, Indian Electricity Grid Code, Electricity Act 2003 and amendments, National Electricity Policy, Deviation Settlement mechanism, Retail Competition.
MODULE IV: Tariff Regulations (10 Hours)
Annual Revenue Requirements, Tariff Structure, Role of State/Central Regulatory Commissions, involved costs – energy purchase, losses, surcharges, O&M, Interests, Depreciation, return on Equity, Total Revenue Requirement, Tariff Policy, Understanding tariff order.
MODULE V: Policies for Renewable Energy (11 Hours)
Renewable Energy Policy, Incentives and subsidies, Foreign Investment, Role of MNES, IREDA, Bio Energy Policy, Solar Policy, National Solar Mission, Waste Management Practices and policies, Renewable purchase obligations, Feed in Tariffs, Renewable Energy Certificates, Hydro Power Policy, Small/Large Scale Hydro Power Plants, PSH, National policy on Hydropower in India, India EV Policy, Other schemes – Saubhagya, UJALA, UDAY, RFMS, Smart Cities, etc.

Text books

1. Alessandro Rubino, Alessandro Sapio, Massimo La Scala, Handbook of Energy Economics and Policy_ Fundamentals and Applications for Engineers and Energy Planners-Academic Press, (2021).
2. Subhes C. Bhattacharyya - Energy Economics_ Concepts, Issues, Markets and Governance-Springer (2019)
3. James M. Griffin and Henry B. Steele (Auth.) - Energy Economics and Policy-Academic Press Inc., (1986).
4. RS Axelrod & SD VanDeveer (Eds.). The Global Environment: Institutions, Law, and Policy. CQ Press; Fifth edition (2019). ISBN 1544330146.
5. TF Braun & MG Lisa. Understanding Energy and Energy Policy. Zed Books,
(2014) ISBN 1780329342.

Reference books

1. Roy L. Nersesian - Energy Economics, Markets, History and Policy-Routledge (2016)
2. Michael G. Webb, Martin J. Ricketts (auth.) - The Economics of Energy-Macmillan Education UK (1980).
3. Kandpal, Tara Chandra, and Hari Prakash Garg. Financial evaluation of renewable energy technologies. MacMillam India Limited, 2003.
4. Nersesian, Roy L. Energy economics: markets, history and policy. Routledge, 2016, ISBN-13: 978-1138858374, ISBN-10: 1138858374.
5. Zweifel, Peter, Aaron Praktiknjo, and Georg Erdmann. Energy economics:
theory and applications. Springer, 2017, ISBN 978-3-662-53022-1.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1	
1.1	Introduction, sector wise consumption of energy resources: Electricity, Fuel, Transportation	1
1.2	Energy Scenario of different sectors: Indian and International Level – Coal, Oil	1
1.3	Natural Gas, RE, Hydro, Nuclear	1
1.4	Global market outlook, import and export position	1

1.5	Resources, Reserves	1
1.6	All India Energy Scenario	1
1.7	Energy Conservation Act 2001 and amendments	1
1.8	Energy Security -Concept, Issues and Economics	1
1.9	Trade-Off between Energy Security and Climate Change	1
MODULE II		
2.1	Time Value of Money Concept	1
2.2	Simple Payback Period	1
2.3	IRR, NPV	1
2.4	Life Cycle Costing	1
2.5	LCA, LCOE	1
2.6	Cost of Saved Energy	1
2.7	Cost of Energy generated	1
2.8	Examples from energy generation and conservation	1
2.9	Energy Chain	1
MODULE III		
3.1	Structure of Indian Power Sector	1
3.2	Structure of Indian Power Sector	1
3.3	Indian Electricity Grid Code	1
3.4	Electricity Act 2003 and amendments	1
3.5	National Electricity Policy	1

3.6	Deviation Settlement mechanism	1
3.7	Retail Competition	1
3.8	Retail Competition	1
3.9	Retail Competition	1
MODULE IV		
4.1	Annual Revenue Requirements	1
4.2	Tariff Structure, Role of State/Central Regulatory Commissions involved costs – energy purchase, losses, surcharges	1
4.3	Tariff Structure, Role of State/Central Regulatory Commissions involved costs – energy purchase, losses, surcharges	1
4.4	O&M	1
4.5	Interests, Depreciation, return on Equity	1
4.6	Interests, Depreciation, return on Equity	1
4.7	Total Revenue Requirement	1
4.8	Tariff Policy	1
4.9	Understanding tariff order	1
4.10	Understanding tariff order	1
MODULE V		
5.1	Renewable Energy Policy, Incentives and subsidies	1
5.2	Foreign Investment, Role of MNES, IREDA	1
5.3	Bio Energy Policy, Solar Policy, National Solar Mission	1
5.4	Waste Management Practices and policies	1

5.5	Renewable purchase obligations, Feed in Tariffs	1
5.6	Renewable Energy Certificates, Hydro Power Policy	1
5.7	Small/Large Scale Hydro Power Plants	1
5.8	PSH, National policy on Hydropower in India	1
5.9	India EV Policy	1
5.10	Other schemes – Saubhagya, UJALA, UDAY, RFMS, Smart Cities, etc.	1
511	Other schemes – Saubhagya, UJALA, UDAY, RFMS, Smart Cities, etc.	1

CO Assessment Questions	
1	Describe the energy scenario of different sectors in Indian and International level with respect to energy supply and demand.
2	Your microwave oven of 1 kW has an efficiency of 65%. The transmission and distribution loss in the electricity network is 8% and the overall average efficiency of the power generation system in the country is 40%. Calculate the quantity of primary fuel will be required to supply you with 1 kWh of energy to run your microwave oven.
3	Describe the energy regulations and policies implemented in Indian Power Sector.
4	An energy saving lamp which consumes 14 W costs Rs.210/- while an incandescent lamp of equivalent luminosity (75 W) costs Rs.52/-. Assuming 10 h of lighting per day and a cost of Rs.10 per kWh of electricity consumption, determine the payback period.
5	Describe the policies and status for renewable energy production through waste management practices in India.

24CHH711	ADVANCED PROCESS CONTROL	L	T	P	J	S	C	Year of Introduction
		4	0	0	0	4	4	2024

Preamble: This course would enable students to gain knowledge on stability analysis using frequency response, transient response of closed and open-loop systems, and their stable and safe range of operation. This course introduces students to some modern methods and tools used for measuring variables in a process industry which are essential for proper control and functioning of all equipment and processes.

Prerequisite: Nil.

Course Outcomes: After the completion of the course the student will be able to

CO1	Describe the various representations of control systems and analyze servo and regulatory problems of closed loop systems.
CO2	Analyze the stability of linear systems using analytical and graphical methods and evaluate controller tuning parameters.
CO3	Apply modern control strategies suitable for specific control applications.
CO4	Determine the dynamics of industrial equipment and choose control valves for a particular application.
CO5	Summarize the concepts of digital process control.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3								
CO2	3	3	3	3		2	2					
CO3	3	3	3	3								
CO4	3	3	3	3								
CO5	3	3	3	3								

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyze			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Mark
		Assignment	Test-1	Test-2	

					s
4-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Open loop and closed loop systems(9 hours)

Open loop and closed loop systems: Importance of modelling for process control - the input-output model, degrees of freedom, input-output model and degrees of freedom in a stirred tank heater. Open loop and closed loop response of LTI systems - Characteristics of second order underdamped step response, Different modes of controllers - P, PI and PID, closed loop response of first and second order systems, Performance criteria of controllers - the error performance indices. Introduction to multivariable control systems, interaction in MIMO systems. Introduction to state space analysis, Definitions of state space, State variables and equilibrium points, representations of systems described by differential equations and transfer functions in state variable form.

MODULE II: Stability Analysis(8 hours)

Stability Analysis: Routh Hurwitz criteria, Bode diagrams, Bode stability criterion, gain margin and phase margin, Nyquist plots – stability analysis using Nyquist stability criteria, Controller tuning - Ziegler-Nichols settings, Cohen-Coon tuning methods, Relay tuning.
MODULE III: Advanced Control Strategies(8 hours)
Advanced Control Strategies: cascade control, ratio control, feed forward control, adaptive control, selective control, inferential control, Smith predictor. Introduction to Model predictive control, PLC and SCADA.
MODULE IV: Process Applications
Process applications: Control valves — characteristics, sizing and valve positioners.

Process identification using Process reaction curve- semi log plot method, First order plus time delay models, Approximation of multi-capacity systems to FOPTD by Skogestad's half rule. Theoretical analysis of complex processes - Dynamics of two plate gas absorber and double pipe heat exchanger.
MODULE V: Sampled Data Control Systems
Sample Data Control systems: Sampling continuous signals, ADC and DAC, Reconstruction of continuous signals from discrete time values, Zero order and first order holds, Basic review of Z transforms, Properties of Z-transforms, inversion of Z-transforms, Response of discrete systems to various inputs - Open loop response to step and impulse inputs, Discrete time analysis of continuous time systems – The Pulse transfer function, Transient response of closed-loop sampled data systems- servo and regulatory problems, mapping, Stability analysis of discrete time systems – stability regions in S and Z planes, Digital approximations of PI and PID controllers.
Text books 1. Coughanowr D.R, Stevan E. LeBlanc Process Systems Analysis & Control, Third Edition, McGraw Hill. 2. Stephanopoulos G., Chemical Process Control, An Introduction to Theory & Practice, Prentice Hall of India. 3. Dale E. Seborg, Thomas F. Edgar and Duncan A. Mellichamp, Process Dynamics and Control, John Wiley& Sons Inc. Second Edition. 4. Katsuhiko Ogata, State space analysis of control systems, Prentice – Hall. 5. Kuo,B.C, Analysis and synthesis of sampled data control systems, Prentice –Hall.

Reference books

1. C.A. Smith and A.B. Corripio. 'Principle and Practice of Automatic Process Control', 3rd Edition., John Wiley and Sons, 2005.
2. W.L. Luyben, Process modeling, Simulation and Control for Chemical Engineers, McGraw Hill.
3. Eckman D.P., Principles of Industrial Process Control, John Wiley & Sons Inc, NY, 1946.
4. Harriot P., Process Control, Tata McGraw Hill.
5. Ceaglske N.H., Automatic Process Control for Chemical Engineers, John Wiley & Sons, NY, 1956.

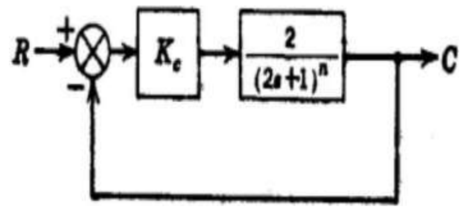
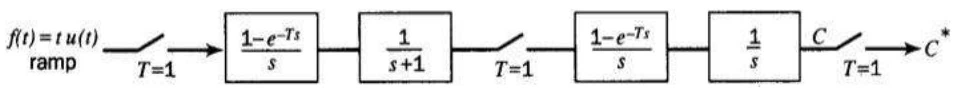
COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE I	
1.1	Open loop and closed loop systems: Importance of modelling for process control, Input-output model, degrees of freedom.	1
1.2	Input-output model and degrees of freedom in a stirred tank heater.	1
1.3	Characteristics of second order underdamped step response.	1
1.4	Different modes of controllers - P, PI and PID,	1
1.5	closed loop response of first and second order systems, offset, integral wind up, derivative kick.	1
1.6	Performance criteria of controllers — the error performance indices.	1
1.7	Introduction to multivariable control systems, interaction in MIMO systems.	1
1.8	Introduction to state space analysis, Definitions of state space, State variables and equilibrium points.	1
1.9	Representations of systems described by differential equations and transfer functions in state variable form.	1
	MODULE II	
2.1	Stability Analysis: Routh Hurwitz criteria.	1

2.2	Bode diagrams.	1
2.3	Bode stability criterion, gain margin and phase margin.	1
2.4	Nyquist plots.	1
2.5	Stability analysis using Nyquist stability criteria.	1
2.6	Controller tuning - Ziegler-Nichols settings.	1
2.7	Controller tuning - Ziegler-Nichols settings.	1
2.8	Cohen-Coon tuning methods, Relay tuning.	1
MODULE III		
3.1	Advanced Control Strategies-Introduction.	1
3.2	Cascade control.	1
3.3	Cascade control.	1
3.4	Feed forward control.	1
3.5	Ratio control.	1
3.6	Smith predictor.	1
3.7	Inferential control, Adaptive control, selective control.	1
3.8	Introduction to Model predictive control, DCS, PLC, SCADA.	1
MODULE IV (10 hours)		
4.1	Process applications: Control valves.	1
4.2	Characteristics, sizing.	1
4.3	Valve positioners.	1
4.4	Process identification using Process reaction curve.	1
4.5	First order plus time delay models (FOPTD), Skogestad's half rule.	1
4.6	Theoretical analysis of complex processes - Dynamics of two plate gas absorber.	1
4.7	Theoretical analysis of complex processes - Dynamics of two plate gas absorber.	1
4.8	Theoretical analysis of complex processes - Dynamics of two plate gas absorber.	1
4.9	Dynamics of double pipe heat exchanger.	1
4.10	Dynamics of double pipe heat exchanger.	1
MODULE V (10 hours)		

5.1	Sample Data Control systems: Discrete time control loops, ADC and DAC.	1
5.2	Sampling and signal reconstruction, zero order and first order hold elements aliasing, guidelines for selecting sampling period.	1
5.3	Basic review of Z transforms, Properties of z-transforms.	1
5.4	Inversion of z-transforms, difference equation to z-transform conversion.	1
5.5	Discrete time analysis of continuous time systems -The Pulse transfer function.	1
5.6	Open loop response to various inputs - step and impulse inputs.	1
5.7	Transient response of closed-loop sampled data systems.	1
5.8	Servo and regulatory problems.	1
5.9	Stability of discrete time systems – mapping from s to z domain, stability regions in s and z planes.	1
5.10	Digital approximations of PI and PID controllers.	1

CO Assessment Sample Questions	
1	1. Consider a process Gp = 0.2/(-s+1), that is open loop unstable. If Gv = Gm = 1, determine whether a proportional controller can stabilize the system. 2. Write short note on the error performance indices method for controller efficiency.
2	1. Using Nyquist stability criterion, investigate the closed-loop stability of a system whose open-loop transfer function is given by, $G(s)H(s) = (s+2)/\ (s+1)(s-1)$ 2. Calculate the value of gain Kc needed to produce continuous oscillations in the control system shown below, when a) n is 2 and b) n is 3 without using graph.

	
3	1. Explain the main features of Smith predictor controller with an example. 2. In a fluidized bed combustor, the fuel to air percentage is to be strictly maintained as 75%, write the main features of the advanced controller suitable for this purpose.
4	1. Describe the equal percentage valve giving emphasis to characteristics and sizing ranges. What are the benefits of equal percentage valve? 2. Derive the transfer function for two-plate gas absorber stating clearly the assumptions involved.
5	1. For the sample data process in figure determine (a) C(z) and b c(nT) for several values of n. 

SEVENTH SEMESTER
MINOR

		L	T	P	J	S	C	Year of Introduction
24CHM709	PROJECT	0	0	0	4	0	4	2024

Preamble: Project in minor focuses on strengthening the understanding of student's fundamental concepts through the application of theoretical concepts and to boost their skills and widen the horizon of their thinking in research. The course will provide an opportunity to identify technology/research gaps and propose innovative/creative solutions. The course will develop skills in doing literature survey, technical presentation and report preparation.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Analyze existing literature in the chosen field or conduct need based analysis and identify research gaps for further investigation
CO2	Conceive a research statement and formulate research objectives.
CO3	Design and implement a well-structured research plan, outlining the key variables, hypotheses and experimental/analytical methods required to address the research questions
CO4	Interpret results effectively to draw meaningful conclusions
CO5	Prepare a technical report and make effective presentations

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	-	2	-	-	-	3	3	-	-	3
CO2	3	3	-	3	-	-	-	-	3	-	-	3
CO3	3	3	3	3	1	-	-	-	3	3	2	3
CO4	3	2	3	-	-	-	-	-	3	3	-	3
CO5	3	-	-	-	-	-	-	3	3	3	-	-

Assessment Pattern

Bloom's Category	Continuous assessment tools		
	Evaluation 1	Evaluation 2	Evaluation 3
Remember			
Understand	✔	✔	✔
Apply	✔	✔	✔
Analyse	✔	✔	✔
Evaluate		✔	✔
Create			

Mark Distribution of CIA

Course Structure [L-T-P-J]	Project guide	Interim Evaluation	Draft Report	Final Report	Final Evaluation	Total Marks
0-0-0-4	25	25	5	10	35	100

Total Mark distribution	
Total Marks	CIA (Marks)
100	100

General guidelines

- Choosing a topic

Project in minor shall be executed as a group activity where each group can have a maximum of four students and shall identify a topic of interest in consultation with Project Coordinator. Review the literature and gather information pertaining to the chosen topic. State the objectives and develop a methodology to achieve the objectives. Carryout the design / fabrication / synthesis / analysis / development of codes or programs to achieve the objectives.

- Evaluation pattern

The progress of the Project is evaluated based on three reviews, two interim reviews and a final review. Students must submit a report during the final review. Credits can be assigned to a student for project if he/she earns a pass grade in the final review.

- Evaluation committee

Continuous Internal Evaluation (CIE) Committee shall comprise of three members. Guide shall be one member in the CIE committee. Final Evaluation Committee shall comprise of three members- department project coordinator, guide and a member nominated by Head of the Department.

EIGHTH SEMESTER

24CHD804 / 24CHN804	PROJECT/INTERNSHIP	L	T	P	J	S	C	Year of Introduction
		0	0	12	0	12	6	2024

Preamble: The objective of the course is to evoke innovation and invention skills in students to solve real-world problems by applying knowledge across domains. Through thorough studies and execution, the project intends to provide meaningful insights into the identified problem and interpretation of results. The project will provide an opportunity to find viable solutions or to develop products, processes, or technology for civil engineering applications.

Prerequisite: Nil

Course Outcomes: After the **completion** of the course the student will be able to

CO1	Analyze existing literature in the chosen field or conduct need-based analysis and identify research gaps for further investigation.
CO2	Conceive a research statement and formulate research objectives.
CO3	Design and implement a well-structured research plan, outlining the key variables, hypotheses and experimental/analytical methods required to address the research questions.
CO4	Interpret results effectively to draw meaningful conclusions.
CO5	Write technical reports by following the rules of scientific writing and deliver well-structured technical presentations

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	-	2	-	-	-	3	3	-	-	3
CO2	3	3	-	3	-	-	-	-	3	-	-	3
CO3	3	3	3	3	1	-	-	-	3	3	2	3
CO4	3	2	3	-	-	-	-	-	3	3	-	3
CO5	3	-	-	-	-	-	-	3	3	3	-	-

Assessment Pattern

Bloom's Category	Continuous assessment tools		
	Evaluation 1	Evaluation 2	Evaluation 3
Remember			
Understand	√	√	√
Apply	√	√	√
Analyse	√	√	√

Evaluate		√	√
Create			

Mark Distribution of CIA							
Course Structure [L-T-P-J]	**Project Guide**	**Interim Evaluation**	**Final Evaluation**	**Draft Report**	**Final Report**	**Poster**	**Total mark**
0-0-12-0	25	20	30	5	15	5	**100**

Total Mark distribution	
Total Marks	**CIA (Marks)**
100	100
General guidelines	

- The research-based project in the seventh semester shall be continued as the project in the eighth semester
- One-third of the project shall be completed in the VII semester and two-third in the VIII semester.

Choosing a topic

The project shall be executed as a group activity where each group can have a maximum of four students on the topic selected for the course research-based project in the seventh semester in consultation with the Project Coordinator. An in-depth study pertaining to the chosen objectives and a methodology to achieve the objectives is expected from students.
Carry out the design/fabrication/synthesis/analysis/development of codes or programs to achieve the objectives.

Internship

- The students can opt internship during the eighth semester which shall also be treated as their project in the eighth semester and shall be evaluated in the same pattern. The minimum duration of such internships shall be 3 months and above and to be approved by the concerned department. Students who opt for this internship can avail of MOOCs or follow self-study mode to meet the credit requirements of the courses in the eighth-semester course mentioned in the curriculum. In such cases, the statement of attendance from the organization where the student pursued his/her internship will be treated as an attendance requirement for internal assessment and end-semester examinations. If the student is permitted to follow self-study mode, he/she is liable to meet all the requirements such as attending internal exams and submitting the assignments and other works given by the course tutor in time.
- Students who opted for internship in the eighth semester have to attend the interim and final project evaluation, by submitting the internship report. Internal internship supervisor shall be a member of the project evaluation committee along with other project evaluation committee members, it is desirable that
  external supervisor from industry also shall be a member of the evaluation

committee of such students along with other project evaluation committee members.

- The students can undertake projects in Central/State PSUs, Government/LSG Departments, and Private Sector industries. The following Government sector institutions can be opted by the students.
- Internships offered by Maharatna, Navaratna & Miniratna CPSEs.
- Internships offered by institutions of national importance.
- Internships offered by the Department of Science and Technology (DST), Council of Scientific & Industrial Research (CSIR), and the Department of Biotechnology (DBT) laboratories.
- Internships offered by the Indian Space Research Organization (ISRO), Defence Research and Development Organization (DRDO), Bhabha Atomic Research Centre (BARC), Hindustan Aeronautics Limited (HAL) and Tata Institute of Fundamental Research (TIFR).

- Generalized points that need to be taken care of by the students during the report preparation of in-plant training (internship in Chemical Industries) are:
  - Company Profile, List of Raw Materials/Products, etc. of the industry & production capacity
  - P & I Diagram, Process Flow Diagram
  - Chemical Reactions involved, Unit Operation & Processes Involved
  - Energy & Material Balance Calculations
  - Process and mechanical design of atleast one equipment (Reactor/Storage Tank/Heat Exchange Equipment/Distillation Column/Absorber/stripper/Cooling Tower, etc.)
  - Treatment & handling of various waste materials which may include liquid effluent handling, air pollution control measures, and solid waste handling and disposal.
  - Safety measures of the plant site: Process safety, PPEs, color coding & Symbols, types of permits, Fire Extinguishers, etc.

Evaluation pattern

The progress of the Project is evaluated based on three reviews, two interim reviews and a final review. Students must submit a report during the final review.

All students doing a project in the eighth semester shall prepare a poster as part of their project highlighting their work. The poster carries 5% weightage of the total marks of the project course and to be prepared based on the guidelines issued time to time.

Evaluation Committee

The Continuous Internal Evaluation (CIE) Committee shall comprise of three members. The guide shall be one member of the CIE committee. The final Evaluation Committee shall comprise of three members - department project coordinator, guide, and a member nominated by the Head of the Department.

Evaluation by the Guide

The guide/supervisor must monitor the progress being carried out by the project groups on regular basis. In case it is found that progress is unsatisfactory it should be reported to the Department Evaluation Committee for necessary action. The presence of each student in the group and their involvement in all stages of execution of the project shall be ensured by the guide.

This evaluation by the guide should be done by considering the following aspects:

- Project Scheduling & Distribution of Work among Team members: Detailed and extensive scheduling with timelines must be provided for each phase of the project. The breakdown of work structure must be well defined.
- Student's Diary/ Daily Log: The main purpose of writing daily diary is to cultivate the habit of documenting and to encourage the students to search for details. It develops the students' thought process and reasoning abilities. The students should record in the daily/weekly activity diary the day-to-day account of the observations, impressions, information gathered and suggestions given, if any. It should contain the sketches & drawings related to the observations made by the students. The daily/weekly activity diary shall be signed after every day/week by the guide.
- Individual Contribution: The contribution of each student at various stages should be documented.
- Completion of the project: The students should demonstrate the project to their respective guide. The guide shall verify the results and see that the objectives are met.

EIGHTH SEMESTER

PROFESSIONAL ELECTIVE-4

24CHE811	PROCESS DESIGN FOR POLLUTION CONTROL	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: The objective of the course is to impart knowledge in various pollution prevention and control techniques. The course content includes Environmental regulations, definition of pollutant, types of pollution, process design of water pollution control equipments, process design of water pollution control equipments, process design of air pollution control equipments, bio medical waste.

Prerequisite: Nil

Course Outcomes: After the **completion** of the course the student will be able to

CO1	State various environmental laws and regulations aimed at the protection of the environment
CO2	Summarize various water and air pollution standards
CO3	Design water, air, and biomedical pollution control systems
CO4	Select and use a suitable treatment technique for biomedical waste

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3				2	2					
CO2	3	3				2	2					
CO3	3	3	2			2	2					
CO4	3	3				2	2					

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	**Attendance**	**Theory [L- T]**			**Total Marks**
		Assignment	**Test-1**	**Test-2**	
3-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 hrs

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I : Prevention vs control of industrial pollution

Prevention vs control of industrial pollution, Environment policies and Regulations to encourage pollution prevention, Environment friendly chemical processes, Regulations for clean environment and implications in industries

MODULE II : Type of pollutants and standards

Definition of pollutant, types of pollution; Air, Water, Land, noise- adverse effects of pollutants, eco system and human health - need for effluent treatment and toxicity, control. Water standards for portable, agricultural and left-off streams-air standards for cities, industrial areas, resort
MODULE III : Design of pollution control equipment : water pollution
Design of Equalization Tank, Sedimentation tank, Oil and grease removal unit, aerator and settling tank of an Activated sludge process, Trickling filter, secondary clarifier, Design of Rotating Biological Contactor.
MODULE IV : Design of pollution control equipment: water pollution
Design of Oxidation pond and Oxidation Ditch, Anaerobic Filter, Two step Anaerobic Digestion System ,Design of Sludge Digester and Sludge Thickener, Air stripping tower
MODULE V : Design of pollution control equipment: air pollution
Process design of cyclone separators, fabric filters and Electrostatic precipitators, Baghouses, gravity settler, SO_2 Scrubbers Scrubbers. Characterization of medical waste- Bio-medical wastes, biomedical waste categories. Process design of Incinerator

Text books

1. Freeman.H.M, "Industrial Pollution Prevention Hand Book", McGraw Hill,1995
2. Ray T.K., " Air Pollution Control in Industries", Volume I, TBI, New Delhi

Reference books

1. C S Rao, Environmental Pollution Control Engineering, New age International
2. C. C. Lee, Shun Dar Lin, Handbook of Environmental Engineering Calculations,
3. Second Edition, McGraw Hill
4. S.P.Mahajan Pollution Control in process industries, Tata McGraw Hill, 1990Connwell & Devis, Introduction to Environmental Engineering, TMH.
5. Frank R. Spellman, Handbook of Water and Wastewater Treatment Plant Operations,CRC Press
6. Metcalf & Eddy, Wastewater Engg. TMHS.J.Arceivala, Wastewater treatment for pollution control, TMH

COURSE CONTENTS AND LECTURE SCHEDULE

No.		**No. of Hours**
MODULE 1 (6 hours)		
1.1	Prevention vs control of industrial pollution	1

1.2	Environment policies and Regulations to encourage pollution prevention	1
1.3	Environment policies and Regulations to encourage pollution prevention	1
1.4	Environment friendly chemical processes	1
1.5	Environment friendly chemical processes	1
1.6	Regulations for clean environment and implications for industries	1
MODULE II (6 hours)		
2.1	Definition of pollutant, types of pollution; Air, Water, Land, noise	1
2.2	adverse effects of pollutants ecosystem and human health	1
2.3	need for effluent treatment and toxicity control.	1
2.4	Water standards for portable, agricultural and left-off streams- air standards for cities, industrial areas, resort	1
2.5	Water standards for portable, agricultural and left-off streams- air standards for cities, industrial areas, resort	1
2.6	Water standards for portable, agricultural and left-off streams- air standards for cities, industrial areas, resort	1
MODULE III (8 hours)		
3.1	Design of Equalization Tank	1
3.2	Sedimentation tank,	1
3.3	Oil and grease removal unit,	1
3.4	aerator and settling tank of an Activated sludge process	1
3.5	aerator and settling tank of an Activated sludge process	1

3.6	Trickling filter, secondary clarifier	1
3.7	Design of Rotating Biological Contactor	1
3.8	Design of Rotating Biological Contactor.	1
MODULE IV (8 hours)		
4.1	Design of Oxidation pond and Oxidation Ditch	1
4.2	Design of Oxidation pond and Oxidation Ditch	1
4.3	Anaerobic Filter	1
4.4	Two step Anaerobic Digestion System	1
4.5	Two step Anaerobic Digestion System	1
4.6	Design of Sludge Digester and Sludge Thickener	1
4.7	Design of Sludge Digester and Sludge Thickener	1
4.8	Air stripping tower	1
MODULE V (8 hours)		
5.1	Process design of cyclone separators	1
5.2	Process design of cyclone separators	1
5.3	fabric filters and Electrostatic precipitators	1
5.4	Baghouses, gravity settler	1
5.5	SO_2 Scrubbers Scrubbers	1
5.6	characterization of medical waste- Bio-medical wastes, biomedical waste categories.	1
5.7	Process design of Incinerator	1
5.8	Process design of Incinerator	1

CO Assessment Questions	
1	Explain the important toxic components in industrial effluents and their control methods
2	Explain the quality standards for potable water
3	Calculate the sludge digester capacity required for the single stage floating cover sludge digester for the sewage treatment of a city, with the following data: Population equivalent=7,000 Loading rate= 0.09 kg/capita/day Volatile solids in the raw sludge = 70 per cent Moisture content of raw sludge = 96 per cent Digestion period = 25 days Volatile solids reduction during digestion = 50 per cent Moisture content of digested sludge= 92 per cent Storage period required for the digested sludge = 90 days
	Design an oxidation pond for treating sewage from a hot climatic residential colony with 5000 persons, contributing sewage at 120 litres per capita per day (LPCD). The 5-day BOD of sewage is 300 mg/L
4	Write the design features of a Biomedical Incinerator along with its neat sketch.

24CHE821	RESCUE AND DISASTER MANAGEMENT	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: The course is intended to provide a general concept in the dimensions of
disasters caused by nature beyond the human control as well as the disasters and environmental hazards induced by human activities with emphasis on rescue, disaster preparedness, response and recovery.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Explain the importance of disaster management
CO2	Summarize the various risk analysis techniques
CO3	Explain the need for disaster preparedness
CO4	Explain the various measures of rescue in different scenarios

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3				2	2					
CO2	3	3				2	2					
CO3	3	3				2	2					
CO4	3	3				2	2					

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	

2-1-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 hrs

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS
MODULE I : Introduction (5 hours)
Definitions:- Hazard, Risk, Vulnerability, Disaster-Meaning, Nature Importance, Dimensions and scope of Disaster Management; Disaster Management Cycle, The Disaster Management Act 2005
MODULE II : Risk Assessment & Reduction (10 hours)
Risk analysis techniques; Process of Risk assessment, Analytical systems for risk assessment, Natural hazard/ risk assessment, Understanding climate risk, Mapping of risk assessment, Decision making for risk reduction, Problems in risk assessment Participatory risk assessment - Rationale for people's participation, Role of civil society organizations, Impact of Globalization, Activities and roles for the community action Risk reduction, Participatory risk assessment methods
MODULE III : Disaster Preparedness (5 hours)

Disaster Preparedness: concept and significance Measures, Institutional Mechanism, Disaster preparedness with special needs/ vulnerable groups, Policy and Programmes
MODULE IV : Introduction to rescue (9 hours)
Introduction To Search Technique, Correct Method Of Searching A Room, Factors Influencing Search & Rescue, Types Of Searches, Factors While Searching, Rescue Technique, Shelter In Place, Exit Assist, Rescue By Fireman, Fireman's Lift, Rescue Using Fire Services Equipments, Ladders And Hydraulic Platforms, Requisite Qualities Of Rescuer, Different Rescue Scenarios.

MODULE V : Various Rescues Scenarios (7 hours)
Rescue In Mines And Shafts, Road Accident (Highway) Rescue, Rescue From High Rise Buildings, Rescue Using Chair Knot, Collapse Of Building/ Judgment Of Collapse, Precautions While Rescue, Rescue Problems In Case Of High Rise Building, Rescue In Case Of Poisonous Gas Leak, Rescue In Sewer Line, Rescue In Case Of Electrical Appliances.
Text books 1. Carter, W. Nick,1991.Disaster Management: A Disaster Manager's Handbook, Asian Development Bank, Manila 2. Green Stephen.1980. International Disaster Relief: Towards A Responsive systems, Mc Graw Hill Book Company, New York. 3. Prakash, Indu , 1995, Disaster Management, Rashtra Prahari Prakashan, Gaziabad
Reference books 1. Elementary principles of rescue by Got. Of India, ministry of Home Affairs 2. Rescue Service Manual by HMSO 3. Rescue –Civil defense handbook by HMSO 4. Penn Well, "Technical rescue operation", volume- II; Larry Collins

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1	
1.1	Definitions:- Hazard, Risk, Vulnerability	1
1.2	Disaster-Meaning, Nature Importance	1
1.3	Dimensions and scope of Disaster Management	1

1.4	Disaster Management Cycle	1
1.5	The Disaster Management Act 2005	1
MODULE II		
2.1	Risk analysis techniques; Process of Risk assessment	1
2.2	Analytical systems for risk assessment	1
2.3	Natural hazard/ risk assessment, Understanding climate risk	1
2.4	Mapping of risk assessment, Decision making for risk reduction	1
2.5	Problems in risk assessment Participatory risk assessment - Rationale for people's participation	1
2.6	Role of civil society organizations, Impact of Globalization	1
2.7	Activities and roles for the community action Risk reduction	1
2.8	Activities and roles for the community action Risk reduction	1
2.9	Participatory risk assessment methods	1
2.10	Participatory risk assessment methods	1
MODULE III		
3.1	Disaster Preparedness: concept and significance Measures	1
3.2	Disaster Preparedness: concept and significance Measures	1
3.3	Institutional Mechanism	1
3.4	Disaster preparedness with special needs/ vulnerable groups	1
3.5	Policy and Programmes	1

MODULE IV		
4.1	introduction to search technique	1
4.2	correct method of searching a room	1
4.3	factors influencing search & rescue, types of searches, factors while searching, rescue technique	1
4.4	factors influencing search & rescue, types of searches, factors while searching, rescue technique	1
4.5	shelter in place, exit assist	1
4.6	rescue by fireman, fireman's lift	1
4.7	rescue using fire services equipments	1
4.8	ladders and hydraulic platforms, requisite qualities of rescuer	1
4.9	different rescue scenarios	1
MODULE V1		
5.1	rescue in mines and shafts	1
5.2	road accident (highway) rescue	1
5.3	rescue from high rise buildings	1
5.4	rescue using chair knot, collapse of building/ judgment of collapse	1
5.5	rescue problems in case of high rise building,	1
5.6	rescue in case of poisonous gas leak, rescue in sewer line	1
5.7	rescue in case of electrical appliances.	1

CO Assessment Sample Questions	
1	Explain the scope of disaster management.
2	List the components of risk assessment. Explain the contemporary approaches to risk assessment
3	Explain the institutional mechanism for disaster preparedness.
4	Explain the rescue operation to be carried out for disaster in mines.

24CHE831	STATISTICAL DESIGN AND ANALYSIS OF EXPERIMENTS	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: Students, researchers, and engineers want to analyze the experimental data scientifically and rigorously and communicate the outcomes in reports, theses, or publications unambiguously. From a basic knowledge of calculus, linear algebra, probability, and statistics the course enables the participants to acquire knowledge and skills in statistical data analysis and design of experiments. The course will introduce essential tools for data analysis by discussing popular probability distributions, the concept of random samples, linear regression, and hypothesis testing. The course is planned to provide an overview of factorial design, orthogonal designs, higher-order designs, and guidelines for selecting the most appropriate design for an experiment.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Develop and interpret the graphical representation of data.
CO2	Analyze the data using descriptive statistics.
CO3	Distinguish the properties and applications of important statistical distributions.
CO4	Analyze the data using inferential statistics.
CO5	Develop and interpret the linear regression analysis.
CO6	Compare different experimental design strategies.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3		3	3							
CO2	3	3		3	3							
CO3	3	3		3	3							
CO4	3	3		3	3							
CO5	3	3		3	3							
CO6	3	3		3	3							

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyze			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	

3-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	3 Hrs

End Semester Examination [ESE]: Pattern

PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10=20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS
MODULE I: Graphical representation of data (8 Hrs)
Bar Charts, Histograms, dot plot, Pie Charts, Scatter Plots, Line Charts, Bubble Plots, box and whisker plots, Interval plots, stem and leaf plots. Descriptive statistics: Mean, Standard Error, Median, Mode, Standard Deviation, Sample Variance, Kurtosis, Skewness, Confidence Level, Quartile, Percentile Development and interpretation of the above terms in any of the software's (say, MS Excel, Matlab, R, etc., Not for End semester examination)
MODULE II: Probability and statistical distributions (7 Hrs)
Probability and statistical distributions: Probability, Properties and applications of important statistical distributions such as normal, log-normal and t-distributions, Chi-Square and F distributions Development and interpretation in any of the softwares (say, MS Excel, Matlab, R etc., Not for End semester examination)
MODULE III: Hypothesis Testing (7 Hrs)

Hypothesis Testing: Formulation of null and alternate hypotheses, errors in hypothesis Tests, power of hypothesis tests, hypothesis tests on population means and variances Single factor experiments: Introduction to Analysis of Variance (ANOVA), blocking and randomization. Development and interpretation in any of the softwares (say, MS Excel, Matlab, R etc., Not for End semester examination)
MODULE IV: Linear Regression Analysis & Factorial Design of Experiments (7 Hrs)
Linear Regression Analysis: Matrix approach to linear regression, ANOVA in regression analysis, quantifying regression fits of experimental data.

Factorial Design of Experiments: Need for planned experimentation, factorial design experiments involving two factors, effect of interactions, ANOVA in factorial design, general factorial design, partial factorial designs Development and interpretation in any of the softwares (say, MS Excel, Matlab, R etc., Not for End semester examination)
MODULE V: Comparison of different experimental design strategies (7 Hrs)
Comparison of different experimental design strategies: Properties of orthogonal designs, implications of different factorial design models, importance of center runs, central composite design, Box Behnken design, rotatable of experimental designs, face-centered cuboidal designs, comparison of experimental designs Development and interpretation in any of the softwares (say, MS Excel, Matlab, R etc., Not for End semester examination)
Textbooks 1. Montgomery D. C., Design and Analysis of Experiments, 8th edition, New Delhi: Wiley-India, 2011.
Reference books 1. Statistics for Engineers and Scientists, William Navidi, 3rd Edition, McGraw Hill 2. Myers R. H., Montgomery D. C. and Anderson C. M., Response Surface Methodology, 3rd edition, New Jersey: Wiley, 2009. 3. Ogunnaike B. A., Random Phenomena, Florida: CRC Press, 2010.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1	
1.1	Bar Charts, Histograms, dot plot, Pie Charts	1
1.2	Scatter Plots, Line Charts, Bubble Plots	1
1.3	Box and whisker plots, Interval plots, stem and leaf plots	1
1.4	Descriptive statistics: Mean, Standard Error, Median, Mode	1
1.5	Standard Deviation, Sample Variance, Kurtosis	1
1.6	Skewness, Confidence Level, Quartile, Percentile	1
1.7	Exercise problems	1
1.8	Exercise problems	1
	MODULE II	
2.1	Introduction to Probability	1

2.2	Introduction to Probability- contd.	1
2.3	Properties and applications of normal distribution	1
2.4	Properties and applications of log-normal distribution	1
2.5	Properties and applications of t-distribution	1
2.6	Properties and applications of Chi-Square distribution	1
2.7	Properties and applications of F distribution	1
MODULE III		
3.1	Hypothesis Testing: Formulation of null and alternate hypotheses	1
3.2	Errors in hypothesis Tests	1
3.3	Power of hypothesis tests	1
3.4	Hypothesis tests on population means and variances	1
3.5	Single factor experiments:Introduction to Analysis of Variance (ANOVA)	1
3.6	Analysis of Variance (ANOVA) - case studies	1
3.7	Blocking and randomization	1
MODULE IV		
4.1	Linear Regression Analysis: Matrix approach to linear regression	1
4.2	ANOVA in regression analysis,	1
4.3	Quantifying regression fits of experimental data.	1
4.4	Need for planned experimentation, factorial design experiments involving two factors	1
4.5	Factorial Design of Experiments: effect of interactions	1
4.6	ANOVA in factorial design,	1
4.7	General factorial design, partial factorial designs	1
MODULE V		
5.1	Properties of orthogonal designs	1
5.2	Implications of different factorial design models	1
5.3	Importance of center runs	1
5.4	Central composite design and Box Behnken design	1
5.5	Rotatable of experimental designs	1
5.6	Face-centered cuboidal designs	1
5.7	Comparison of experimental designs	1

CO Assessment Sample Questions	
1	Develop the Stem-and-Leaf Plot for the following data of durations (in minutes) for completion of the reaction.
2	Find the first and third quartiles of the sample values of fracture stress (in megapascals) measured for a sample of 24 mixtures of hot-mixed asphalt (HMA). Data: 30, 75, 79, 80, 80, 105, 126, 138, 149, 179, 179, 191, 223, 232, 232, 236, 240, 242, 245, 247, 254, 274, 384, 470
3	State and explain the Central Limit Theorem

4	Give the Steps in Performing a Hypothesis Test

5	A chemical engineer is studying the effect of temperature and stirring rate on the yield of a certain product. The process is run 16 times, at the settings indicated in the following table. The units for yield are percent of a theoretical maximum.

Temperature(∘C)	Stirring Rate (rpm)	Yield (%)
110	30	70.27
110	32	72.29
111	34	72.57
111	36	74.69
112	38	76.09
112	40	73.14
114	42	75.61
114	44	69.56
117	46	74.41
117	48	73.49
122	50	79.18
122	52	75.44
130	54	81.71
130	56	83.03
143	58	76.98
143	60	80.99

(a) Compute the correlation between temperature and yield, between stirring rate and yield, and between temperature and stirring rate.
(b) Do these data provide good evidence that increasing the temperature causes the yield to increase, within the range of the data? Or might the result be due to confounding? Explain.
(c) Do these data provide good evidence that increasing the stirring rate causes the yield to increase, within the range of the data? Or might the result be due to confounding? Explain.

6	Differentiate between central composite design and Box Behnken design of response surface methodology.

24CHE841	ENHANCED OIL RECOVERY	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: The objective of the Enhanced Oil Recovery (EOR) course is to provide students with a comprehensive understanding of advanced techniques and methodologies employed in maximizing hydrocarbon recovery from reservoirs. Students will gain insights into reservoir behavior, fluid dynamics, and the various EOR processes such as water flooding, gas injection, chemical flooding, and thermal methods. By the end of the course, students should be proficient in assessing reservoir conditions, designing EOR strategies, and making informed decisions to optimize oil recovery while considering economic and environmental factors.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Explain different EOR types and their functions and enlist the different indicators/measures used to evaluate the EOR performance.
CO2	List different chemicals/agents used for different EOR techniques and explain their functions in enhancing oil recovery.
CO3	Describe the underlying mechanisms that cause oil recovery in different EOR techniques.
CO4	Explain the field implementation and performance evaluation of different EOR techniques.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2										
CO2	3	2										
CO3	3	2										
CO4	3	2										

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyze			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 Hrs

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10=20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub-divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Fundamentals of EOR (7 Hrs)

Global and domestic necessity for EOR; India's EOR policy; microscopic and macroscopic displacement of fluids in reservoir; mobilization of trapped oil; mobility control; EOR performance indicators – Capillary Number, mobility ratio, breakthrough from fractional flow curves, wettability alteration from relative permeability curves; recovery factor – volumetric displacement and microscopic displacement efficiency; overview of waterflooding process; different EOR methods and its functions; EOR screening.

MODULE II: Chemical EOR Methods – I (8 Hrs)

Surfactant flooding EOR: Oil recovery mechanism by surfactants, surfactant types & its functions; CMC; microemulsion – types & its phase behavior; field implementation of surfactant flooding EOR; performance evaluation and screening of surfactants.

Polymer flooding EOR: Oil recovery mechanism by polymers; mobility control; polymer types & its behavior under reservoir conditions; field implementation of polymer flooding EOR; performance evaluation and screening of polymers for EOR.

Alkaline-Surfactant-Polymer (ASP) flooding EOR: Role of alkaline in oil recovery; oil recovery mechanism and field implementation of ASP flooding EOR; performance evaluation of ASP EOR.

MODULE III: Chemical EOR Methods – II (8 Hrs)
Low salinity water flooding (LSWF) EOR: Oil recovery mechanisms – Double layer expansion, MIE process, pH alteration, fines migration, etc.; evaluation of wettability alteration from rel. permeability curves; field implementation; challenges in LSWF EOR. Microbial EOR (MEOR): Different types of microbes and bioproducts and its role in oil recovery; MEOR types and its oil recovery mechanism; field implementation and performance evaluation of MEOR; Merits and challenges in implementing MEOR. Hybrid EOR techniques: Oil recovery mechanism of Low salinity surfactant flooding, Low salinity polymer flooding.

MODULE IV: Gas EOR Methods & CO_2 Sequestration (7 Hrs)
Gases used for EOR; Gas EOR types; MMP; immiscible gas flooding EOR; miscible flooding EOR – first contact miscibility and multiple contact miscibility – vaporization, condensation, and combined drive mechanism; ternary phase diagrams for immiscible and miscible gas flooding EOR mechanisms. Field implementation and oil recovery mechanism of continuous gas injection, CO_2 flooding, WAG, SWAG, SSWAG EOR process. Necessity for CO_2 sequestration; CO_2 sequestration in aquifers and oil reservoirs; CO_2 trapping mechanisms – Structural, hydrodynamic, residual, dissolution, and mineral trappings. Challenges in CO_2 sequestration.
MODULE V: Thermal EOR Methods (6 Hrs)
Types of thermal EOR and its oil recovery mechanism, advantages, and constraints – Hot water flooding, steam flooding, cyclic steam flooding or huff & puff steam flooding, steam-assisted gravity drainage, in-situ combustion oil recovery technique.
Textbooks 1. Enhanced Oil Recovery. SPE (2018): Don W. Green and G. Paul Willhite. 2. Van Poollen, H.K. "Fundamentals of enhanced oil recovery", Penn Well Books, 1980.
Reference books 1. Fundamentals of Enhanced Oil Recovery. SPE (2015): Larry W. Lake, Russell Johns, Bill Rossen, Gary Pope. 2. Fundamentalof enhanced oil and gas recovery from conventional and unconventional reservoirs (2018): Alireza Bahadori.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1	
1.1	Global and domestic necessity for EOR; India's EOR policy;	1
1.2	microscopic and macroscopic displacement of fluids in reservoir; mobilization of trapped oil; mobility control;	1
1.3	EOR performance indicators – Capillary Number, mobility ratio,	1

	breakthrough from fractional flow curves,	
1.4	wettability alteration from relative permeability curves; recovery factor – volumetric displacement and microscopic displacement efficiency;	1
1.5	overview of the waterflooding process;	1
1.6	different EOR methods and its functions;	1
1.7	EOR screening.	1
	MODULE II	
2.1	Surfactant flooding EOR: Oil recovery mechanism by surfactants,surfactant types & its functions;	1
2.2	CMC; microemulsion – types & its phase behavior; field implementation of surfactant flooding EOR;	1
2.3	performance evaluation and screening of surfactants.	1
2.4	Polymer flooding EOR: Oil recovery mechanism by polymers;mobility control;	1
2.5	polymer types & its behavior under reservoir conditions; field implementation of polymer flooding EOR;	1
2.6	performance evaluation and screening of polymers for EOR.	1
2.7	Alkaline-Surfactant-Polymer (ASP) flooding EOR: Role of alkaline in oil recovery;	1
2.8	oil recovery mechanism and field implementation of ASP flooding EOR; performance evaluation of ASP EOR.	1
	MODULE III	
3.1	Low salinity water flooding (LSWF) EOR: Oil recovery mechanisms – Double layer expansion, MIE process, pH alteration, fines migration,etc.;	1
3.2	evaluation of wettability alteration from rel. permeability curves; field implementation; challenges in LSWF EOR.	1
3.3	Microbial EOR (MEOR): Different types of microbes and bioproducts and its role in oil recovery;	1
3.4	MEOR types and its oil recovery mechanism;	1
3.5	field implementation and performance evaluation of MEOR;	1
3.6	Merits and challenges in implementing MEOR.	1
3.7	Hybrid EOR techniques: Oil recovery mechanism of Low salinity surfactant flooding, Low salinity polymer flooding.	1
3.8	Hybrid EOR techniques: Oil recovery mechanism of Low salinity surfactant flooding, Low salinity polymer flooding.	1
	MODULE IV	
4.1	Gases used for EOR; Gas EOR types; MMP; immiscible gas flooding EOR;	1

4.2	miscible flooding EOR – first contact miscibility and multiple contact miscibility – vaporization, condensation, and combined drive mechanism;	1
4.3	ternary phase diagrams for immiscible and miscible gas flooding EOR mechanisms.	1
4.4	Field implementation and oil recovery mechanism of continuous gas injection,	1
4.5	CO_2 flooding, WAG, SWAG, SSWAG EOR process.	1
4.6	Necessity for CO_2 sequestration; CO_2 sequestration in aquifers and oil reservoirs;	1
4.7	CO_2 trapping mechanisms – Structural, hydrodynamic, residual,dissolution, and mineral trappings. Challenges in CO_2 sequestration.	1
MODULE V		
5.1	Types of thermal EOR and its oil recovery mechanism, advantages, and constraints	1
5.2	Hot water flooding, steam flooding,	1
5.3	Hot water flooding, steam flooding,	1
5.4	cyclic steam flooding or huff & puff steam flooding,	1
5.5	steam-assisted gravity drainage,	1
5.6	in-situ combustion oil recovery technique.	1

CO Assessment Sample Questions	
1	(i) List and briefly describe the microscopic displacement mechanisms involved in fluid flow within a reservoir. (ii) Define Enhanced Oil Recovery (EOR) and explain its global significance in the oil and gas industry. (iii) Differentiate between capillary number and mobility ratio. How are these parameters crucial in understanding fluid displacement in reservoirs?
2	(i) Compare and contrast the oil recovery mechanisms of surfactants, polymers,and alkaline in the context of EOR. Highlight their unique contributions to enhanced oil recovery.
3	(i) Explain the phase behavior of microemulsions and categorize the different types of microemulsions used in surfactant flooding EOR.
4	(i) Propose a thermal EOR strategy for a reservoir with specific characteristics,considering factors such as reservoir depth, temperature, and fluid properties. (ii) Explain the concept of cyclic steam flooding (Huff & Puff) and describe how it differs from continuous steam flooding in terms of implementation and oil recovery efficiency.

24CHE851	ELECTROCHEMICAL ENERGY CONVERSION AND STORAGE	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: This course enables the students to get an overview of various electrochemical storage devices. Principles of battery and its performance factors are discussed. This course also discusses the principles of fuel cells & supercapacitors.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Summarize the factors affecting the battery performance
CO2	Summarize the principle, design, construction, performance characteristics and applications of storage batteries
CO3	Explain the testing & evaluation of electrochemical cell
CO4	Describe the principles of fuel cells & supercapacitor

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2										
CO2	3	3				2	2					
CO3	3					1	1					
CO4	3	3				1	1					

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	√	√	√	√
Understand	√	√	√	√
Apply	√	√	√	√
Analyse			√	
Evaluate			√	
Create			√	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS
MODULE I : Introduction (6 hours)
EMF, reversible and irreversible cells, free energy, effect of cell temperature, thermodynamic calculation of the capacity of a battery, calculations of energy density of cells.
MODULE II: Storage Batteries (8 hours)
Principle, design, construction, performance characteristics, advantage and disadvantages. Primary batteries - Zn-MnO2 carbon-zinc. Secondary batteries – lead-acid, nickel-cadmium, Aluminum based batteries, for electric vehicle applications, Micro batteries, Introduction to flow battery
MODULE III : Factors Affecting Battery Performance (9 hours)
Factors affecting battery capacity, voltage level, current drain of discharge, types of discharge: continuous, intermittent, constant current, constant load, constant power, service life, voltage regulation, charging methods, battery age & storage condition.
MODULE IV : Testing & Evaluation (8 hours)

Evaluation of active mass, surface area measurement - BET method. Internal resistance of cells - A.C. methods impedance method. Testing of capacity, retention of charge, vibration, life, efficiency, leakage for sealed cells
MODULE V : Fuel Cells & Supercapacitor (5 hours)
Introduction to super capacitors, types of super capacitors. Introduction to fuel cells, types of fuel cells and technology development. solid oxide fuel cells.
Text books

1. M. Mench, "Fuel Cell Engines", John Wiley, New York, 2008. 2. B. E. Conway, "Electrochemical Supercapacitors : Scientific Fundamentals and Technological Applications", Kluwer Academic / Plenum publishers, New York, 1999.
Reference books 1. Gholam Abbas Nazri, "Lithium Batteries – Science and Technology", Springer, New York, 2009. 2. D.Pavlov, "Lead – Acid Batteries: Science and Technology", Elsevier, Amsterdam, 2011.

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE 1		
1.1	EMF, reversible and irreversible cells	1
1.2	free energy	1
1.3	effect of cell temperature	1
1.4	thermodynamic calculation of the capacity of a battery	1
1.5	calculations of energy density of cells.	1
1.6	calculations of energy density of cells.	1
MODULE II		
2.1	Storage batteries: Principle	1
2.2	Storage batteries: design, construction.	1
2.3	Storage batteries: design, construction.	1

2.4	performance characteristics	1
2.5	advantage and disadvantages.	1
2.6	Primary batteries - Zn-MnO2 carbon-zinc.	1
2.7	Secondary batteries – lead-acid, nickel-cadmium, Aluminum based batteries, for electric vehicle applications Micro batteries.	1
2.8	Introduction to flow battery	1
MODULE III		
3.1	Factors affecting battery capacity.	1
3.2	voltage level, current drain of discharge.	1
3.3	types of discharge: continuous, intermittent, constant current	1
3.4	constant load, constant power, service life, voltage regulation, charging methods	1
3.5	constant load, constant power, service life, voltage regulation, charging methods	1
3.6	constant load, constant power, service life, voltage regulation, charging methods	1
3.7	constant load, constant power, service life, voltage regulation, charging methods	1
3.8	constant load, constant power, service life, voltage regulation, charging methods	1
3.9	battery age & storage condition	1
MODULE IV		
4.1	Evaluation of active mass.	1
4.2	surface area measurement - BET method	1
4.3	Internal resistance of cells - A.C. methods impedance method.	1
4.4	Internal resistance of cells - A.C. methods impedance method	1

4.5	Testing of capacity, retention of charge.	1
4.6	Testing of capacity, retention of charge.	1
4.7	vibration, life, efficiency, leakage for sealed cells	1
4.8	vibration, life, efficiency, leakage for sealed cells	1
	MODULE V	
5.1	Introduction to super capacitors,	1
5.2	types of supercapacitors.	1
5.3	Introduction to fuel cells.	1
5.4	types of fuel cells and technology development.	1
5.5	solid oxide fuel cells	1

CO Assessment Questions (Sample)	
1	Explain the factors affecting the battery performance
2	Distinguish the working of fuel cells and supercapacitors
3	Differentiate between primary battery and secondary battery

24CHE861	PROCESS PLANT SIMULATION	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: Simulation is an invaluable tool in the design and optimization of new processes or modifications to existing ones. Process plant simulation allows engineers to optimize and fine-tune various aspects of plant operations, identify opportunities for cost reduction, and facilitate effective troubleshooting. At the end of the course, students will gain a solid understanding of the fundamental concepts and principles underlying process plant simulation, including the key terminology, methodologies, and theoretical foundations.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to:

CO1	Explain the salient features of simulation and the consideration of physical and thermo-physical properties.
CO2	Analyze the sequential and simultaneous modular approaches to plant simulation, evaluating their respective advantages and limitations.
CO3	Implement the equation-solving approach in plant simulation, including the precedence ordering of equation sets.
CO4	Gain proficiency in convergence promotion methods, including direct substitution, Newton's and quasi-Newton's methods, and Wegstein's method.
CO5	Apply simulation tools to solve engineering problems related to unit operations and chemical processes.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2											
CO2	2	2										
CO3	3			2								
CO4	2			2	3							
CO5	2			2	3							

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 Hrs

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub-divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Introduction to simulation (8 Hrs)

Introduction: Process synthesis and analysis, solving material and energy balance for steady-state processes, equipment sizing and analysis of process flowsheet; salient features of simulation: modular approach, equation solving approach, decompositions of networks, convergence promotion, physical and thermo-physical properties, specific purpose and dynamic simulation.

Classification of mathematical modeling: Independent and dependent variables, model classification based on (i) the type of independent variables (lumped and distributed) (ii) the state of the process (static, dynamic, and complete mathematical models) (iii) the type of the process (deterministic and stochastic)

MODULE II: Experimental results and approaches of plant simulation (8 Hrs)

Treatment of experimental results: Propagation of error through addition, subtraction, multiplication and division, sources of error, error measurement, precision errors, errors of methods, significant figures; data regression: theoretical methods of data regression and the associated problems. Approaches of plant simulation: Modular approach of process plant simulation - analysis vs. design mode, sequential and simultaneous modular approaches; equation-solving approach – precedence ordering of equation sets, disjoining, tearing a system of equations, substitution algorithm, maintaining sparsity.
MODULE III: Decomposition of networks and convergence (8 Hrs)
Decomposition of networks: Tearing algorithms – (i) algorithms based on signal flow graphs: Barkley-Motard algorithm, Pho-Lapidus algorithm; (ii) algorithms based on reduced digraphs: Kehat-Shacham algorithm, Murthy-Hussain algorithm; comparison of

various tearing algorithms. Convergence promotion and thermodynamic properties: Introduction, direct substitution, Newton's and quasi-Newton's methods, Wegstein's method; thermodynamic properties: review of thermodynamic models, sources, data banks, modularity, and routing.
MODULE IV: Professional Simulation Packages and Simulation of Unit Operations (6 Hrs)
Introduction to professional plant simulation packages (ASPEN or equivalent): Basic features, the idea of an integrated simulation environment, package products, interactive process modeling, stepwise methodology of usage to a chemical plant simulation. Simulation of various unit operations using packages (ASPEN or equivalent) (not to be considered for end-semester examination)
MODULE V: Introduction to dynamic simulation (6 Hrs)
Specific purpose simulation and dynamic simulation: Introduction, problem description and formulation, simulation, results-discussion, and inferences of (i) auto-thermal ammonia synthesis reactor (ii) thermal cracking operation, and (iii) design of a shell and tube heat exchanger.
Textbooks 1. B.V. Babu, Process Plant Simulation, Oxford University Press, 2004.

Reference books

1. I.D. Gil Chaves, J.R.G. López, J.L. García Zapata, A. Leguizamón Robayo, G. Rodríguez Niño, Process Analysis and Simulation in Chemical Engineering, Springer International, 2016.
2. W. Reonick, Process Analysis and Design of Chemical Engineers, Wiley-Interscience, 1983.
3. A. Husain, Chemical Process Simulation, Wiley, 1986

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1	
1.1	Introduction: Process synthesis and analysis, solving material and energy balance for steady-state processes	1
1.2	equipment sizing and analysis of process flowsheet;	1
1.3	salient features of simulation: modular approach, equation solving approach	1
1.4	decompositions of networks, convergence promotion	1
1.5	physical and thermo-physical properties, specific purpose, and dynamic simulation.	1
1.6	Classification of mathematical modeling: Independent and dependent variables, model classification based on (i) the type of independent variables (lumped and distributed)	1
1.7	(ii) the state of the process (static, dynamic, and complete mathematical models)	1
1.8	(iii) the type of the process (deterministic and stochastic)	1

	MODULE II	
2.1	Treatment of experimental results: Propagation of error through addition, subtraction, multiplication, and division	1
2.2	sources of error, error measurement, precision errors, errors of methods, significant figures	1
2.3	data regression: theoretical methods of data regression and the associated problems.	1
2.4	Approaches of plant simulation: Modular approach of process plant simulation - analysis vs. design mode	1
2.5	sequential and simultaneous modular approaches;	1
2.6	equation-solving approach – precedence ordering of equation sets,	1

2.7	disjoining, tearing a system of equations	1
2.8	substitution algorithm, maintaining sparsity	1
MODULE III		
3.1	Decomposition of networks: Tearing algorithms – (i) algorithms based on signal flow graphs: Barkley-Motard algorithm, Pho-Lapidus algorithm;	1
3.2	(ii) algorithms based on reduced digraphs: Kehat-Shacham algorithm	1
3.3	Murthy-Hussain algorithm; comparison of various tearing algorithms.	1
3.4	Convergence promotion and thermodynamic properties: Introduction, direct substitution,	1
3.5	Newton's and quasi-Newton's methods,	1
3.6	Wegstein's method;	1
3.7	thermodynamic properties: review of thermodynamic models,	1
3.8	sources, data banks, modularity, and routing.	1
MODULE IV		
4.1	Introduction to professional plant simulation packages (ASPEN or equivalent): Basic features	1
4.2	the idea of an integrated simulation environment, package products.	1
4.3	interactive process modeling, stepwise methodology of usage to a chemical plant simulation.	1
4.4	Simulation of various unit operations using packages (ASPEN or equivalent) (not to be considered for end-semester examination)	1
4.5	Simulation of various unit operations using packages (ASPEN or equivalent) (not to be considered for end-semester examination)	1
4.6	Simulation of various unit operations using packages (ASPEN or equivalent) (not to be considered for end-semester examination)	1
MODULE V		
5.1	Specific purpose simulation and dynamic simulation: Introduction	1
5.2	problem description and formulation, simulation, results-discussion, and inferences of (i) auto-thermal ammonia synthesis reactor	1

5.3	problem description and formulation, simulation, results-discussion, and inferences of (i) auto-thermal ammonia synthesis reactor	1

5.4	problem description and formulation, simulation, results-discussion, and inferences of (ii) thermal cracking operation	1
5.5	problem description and formulation, simulation, results-discussion, and inferences of (iii) design of a shell and tube heat exchanger.	1
5.6	problem description and formulation, simulation, results-discussion, and inferences of (iii) design of a shell and tube heat exchanger.	1

CO Assessment Sample Questions	
1	In the context of process plant simulation, explain in detail the salient features of simulation, emphasizing the modular approach, the equation-solving approach, and the decomposition of networks.
2	Compare and contrast the sequential and simultaneous modular approaches in plant simulation. Discuss the advantages and limitations associated with each approach.
3	Describe the equation-solving approach in plant simulation, focusing on the precedence ordering of equation sets.
4	Discuss considerations for selecting the most appropriate convergence promotion method based on the characteristics of the simulation problem.
5	A flash chamber operating at 80 ^{o}C and 500 kPa is separating 1000 kg/hr of a feed that is 10 mol% Ethane, 5% Propane, 15% n-Butane, 10% n-Pentane, 12% iso-Pentane, 8% n-Hexane, 30% Heptane and 10% Nonane. Determine the product compositions and flow rates. Feed conditions are the same as that of the flash chamber. Explain how you would approach and formulate this problem using simulation tools, specifying the simulation package you would employ. Also, analyze and interpret the simulation results to address the engineering problem.

24CHE871	Waste to Energy Conversion	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: This course aims to update the knowledge of students in the area of waste
utilization for energy production through newer technologies. This course provides a comprehensive exploration of waste-to-energy conversion, covering waste characterization, energy production techniques (incineration, gasification, pyrolysis), biochemical and chemical routes, environmental aspects, plastic waste management,
and innovations in energy production from solid wastes.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Characterize different types of waste and analyze the present status of Waste-to-Energy (WTE) technologies.
CO2	Analyze the suitability of different waste-to-energy conversion methods for specific waste types.
CO3	Explain various waste-to-energy techniques, including incineration, gasification pyrolysis.
CO4	Select suitable biochemical/chemical routes for conversion of waste to energy.
CO5	Explain the principles and methodologies in harnessing energy from solid wastes, focusing on efficient techniques such as densification and power plant efficiency improvement.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2					3					
CO2			2					2				
CO3					3					2		
CO4				3				2				
CO5											2	2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
4-0-0-0	5	15	10	10	40

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 hrs

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Introduction to Energy from Waste (7 hours)

Introduction: Definition of wastes and their classification, Important quality parameters of different types of wastes, Waste suitable for energy production, Solid wastes and their classification, Wastewater and their classification. Need of energy production from wastes, present status of WTE technologies. Characterization of solid wastes: Physical, Chemical, Proximate and ultimate analysis, Fusing point of ash, Lignocellulosic composition, Leaching properties, Energy content: Heating value, Characterization of wastewater. Combustion: Nature and types of combustion processes – Mechanism.
MODULE II: Energy Production from Wastes (7 hours)
Energy Production from Wastes: Energy production through incineration, gasification, pyrolysis and syngas utilization. Incineration: principle, Incinerators parts and their types/working, Environmental impact and operational issues, advantages, and

disadvantages; Gasification: principle, advantages, and disadvantages; Pyrolysis: principle, advantages, and disadvantages; Syngas utilization: principle, advantages, and disadvantages.
MODULE III: Energy production through biochemical and chemical routes (8 hours)
Biomass Gasification: Gasifiers – Fixed bed system – Downdraft and updraft gasifiers – Fluidized bed gasifiers – Design, construction and operation. Energy production through biochemical and chemical routes- Energy production through anaerobic digestion, fermentation, transesterification and introduction to microbial fuel cells. Anaerobic digestion: principle, advantages, and disadvantages; Fermentation: principle, advantages, and disadvantages; Transesterification: principle, advantages, and disadvantages; Introduction to microbial fuel cells: principle, advantages, and disadvantages.
MODULE IV: Environmental Aspects (7 hours)
Definition of pyrolysis, mechanism, Types of pyrolysis, Operating conditions and end product distribution, Options for management of plastic wastes and recycling through pyrolysis. Energy Production from Algae: Cultivation of algal biomass from wastewater and energy production from algae. Algae cultivation: principle, advantages, and disadvantages; Energy production from algae: principle, advantages, and disadvantages; Applications of algae in waste management.
MODULE V: Innovations in Mineral Processing Technology (7 hours)

Energy Production from Solid Wastes: Densification of solids, efficiency improvement of power plant and energy production from waste plastics. Densification of solids: principle, advantages, and disadvantages; Efficiency improvement of power plants: principle, advantages, and disadvantages; Energy production from waste plastics: principle, advantages, and disadvantages; Applications of waste plastics in energy generation.
Text books 1. Rogoff, M. J. and Screve, F., "Waste-to-Energy: Technologies and Project Implementation", Elsevier Store, 2011. 2. Young G. C., "Municipal Solid Waste to Energy Conversion processes", John Wiley and Sons, 2010. 3. Harker, J. H. and Backhusrt, J. R., "Fuel and Energy", Academic Press Inc, 1981. 4. EL-Halwagi, M. M., "Biogas Technology – Transfer and Diffusion", Elsevier Applied Science, 1986. 5. Hall, D.O. and Overeed, R.P.," Biomass – Renewable Energy", John Willy and Sons. Mondal, P. and Dalai, A. K. eds., 2017. Sustainable Utilization of Natural Resources. CRC Press.
Reference books 1. Food, Feed and Fuel from Biomass, Challal, D. S., IBH Publishing Co. Pvt. Ltd., 1991. 2. Biomass Conversion and Technology, C. Y. WereKo-Brobby and E. B. Hagan, John Wiley & Sons, 1996

COURSE CONTENTS AND LECTURE SCHEDULE		
No.		No. of Hours
MODULE 1 (7 hours)		
1.1	Introduction: Definition of wastes and their classification, Important quality parameters of different types of wastes.	1
1.2	Waste suitable for energy production, Solid wastes and their classification, Wastewater and their classification	1
1.3	Need of energy production from wastes, present status of WTE technologies.	1
1.4	Characterization of solid wastes: Physical, Chemical, Proximate and ultimate analysis.	1

1.5	Fusing point of ash, Lignocellulosic composition, Leaching properties, energy content: Heating value.	1
1.6	Fusing point of ash, Lignocellulosic composition, Leaching properties, energy content: Heating value.	1
1.7	Characterization of wastewater. Combustion: Nature and types of combustion processes – Mechanism.	1
MODULE II (7 hours)		
2.1	Energy Production from Wastes: Energy production through incineration, gasification, pyrolysis and syngas utilization.	1
2.2	Energy Production from Wastes: Energy production through incineration, gasification, pyrolysis and syngas utilization.	1
2.3	Incineration: principle, Incinerators parts and their types/working.	1
2.4	Environmental impact and operational issues, advantages, and disadvantages.	1
2.5	Gasification: principle, advantages, and disadvantages.	1
2.6	Pyrolysis: principle, advantages, and disadvantages.	1
2.7	Syngas utilization: principle, advantages, and disadvantages.	1
MODULE III (8 hours)		
3.1	Biomass Gasification: Gasifiers – Fixed bed system – Downdraft and updraft gasifiers.	1
3.2	Biomass Gasification: Gasifiers – Fixed bed system – Downdraft and updraft gasifiers.	1
3.3	Fluidized bed gasifiers – Design, construction and operation.	1

3.4	Energy production through biochemical and chemical routes	1
3.5	Energy production through anaerobic digestion, fermentation, transesterification and introduction to microbial fuel cells	1
3.6	Anaerobic digestion: principle, advantages, and disadvantages;	1

3.7	Fermentation: principle, advantages, and disadvantages	1
3.8	Transesterification: principle, advantages, and disadvantages; Introduction to microbial fuel cells: principle, advantages, and disadvantages.	1
MODULE IV (7 hours)		
4.1	Definition of pyrolysis, mechanism, Types of pyrolysis.	1
4.2	Operating conditions and end product distribution.	1
4.3	Options for management of plastic wastes and recycling through pyrolysis.	1
4.4	Energy Production from Algae: Cultivation of algal biomass from wastewater and energy production from algae.	1
4.5	Algae cultivation: principle, advantages, and disadvantages.	1
4.6	Energy production from algae: principle, advantages, and disadvantages.	1
4.7	Applications of algae in waste management.	1
MODULE V (7 hours)		
5.1	Energy Production from Solid Wastes: Densification of solids, efficiency improvement of power plant and energy production from waste plastics.	1
5.2	Energy Production from Solid Wastes: Densification of solids, efficiency improvement of power plant and energy production from waste plastics.	1
5.3	Densification of solids: principle, advantages, and disadvantages.	1
5.4	Efficiency improvement of power plants: principle, advantages, and disadvantages.	1
5.5	Energy production from waste plastics: principle, advantages, and disadvantages.	1

5.6	Energy production from waste plastics: principle, advantages, and disadvantages.	1

5.7	Applications of waste plastics in energy generation.	1

CO Assessment Sample Questions	
CO1	Analyze the present status of Waste-to-Energy (WTE) technologies, highlighting advancements and challenges. How can understanding waste characteristics contribute to the improvement of WTE processes?
CO2	Compare and contrast the suitability of incineration and gasification for different types of waste. Provide examples and justifications.
CO3	Explain about the environmental impact of incineration technology. How does this impact vary based on the characteristics of the waste being incinerated?
CO4	Explain the working principle of Microbial Fuel Cells How can Microbial Fuel Cells contribute to sustainable waste conversion?
CO5	Explain the potential environmental impacts associated with inefficient waste-to-energy processes. Explain how adopting densification and improving power plant efficiency can mitigate these impacts.

24CHE881	COLLOIDS AND INTERFACE ENGINEERING	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: The objective of this course is to introduce students to the fundamentals of colloidal and interfacial phenomena. Students will be exposed to a broad selection of topics, including colloidal suspensions, surface tension, wetting, surfactant adsorption, interparticle interactions etc.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to:

CO1	Explain the fundamental concepts of colloids
CO2	Summarize the importance of interface engineering
CO3	Explain the various methods of synthesis of nanoparticles
CO4	Describe the characterization methods for the analysis of a particle

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3									
CO2	3	3										
CO3	3	3	3									
CO4	3	3	3									

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test 1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 hrs

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 mark s]	

SYLLABUS
MODULE I : Introduction of colloids (6 hours)
Introduction of Colloids, The colloidal state and classification, Importance of colloids, Properties and application of colloid systems, interaction between particles, colloid stability, and aggregation
MODULE II : Introduction to surfactants (7 hours)
Surfactants: classification, properties, applications. Surfactants in solution: micelles, vesicles, Micro emulsions Electrical phenomena at interfaces: Electric double layer, zeta potential, DLVO theory
MODULE III : Introduction to interface engineering (8 hours)
Surface free energy, films on liquid substrates (mono-molecular films, Langmuir-Blodgett layers), Adsorption-Langmuir and Gibbs adsorption isotherm, Types of Interface (Solid-Gas, Solid-liquid, liquid -gas, liquid-liquid) and its features
MODULE IV : Synthesis methods (6 hours)
Flocculation, Coagulation, Electrokinetics, and Rheology of dispersions, Porous materials and membranes, Thin films, Surfactant assisted nanoparticle synthesis, Applications of colloid and interfacial science.
MODULE V : Characterization methods (9 hours)
Particle Size, Surface area, Volume, Equivalent Diameter and Aerodynamic Diameter Measurement Methods – Microscopy, Optical Counter, Electrical Aerosol Analyzer, Bacho Microparticle classifier, Particle Size analyzer. Particle mass, Volumetric flow rate and average particle concentration calculation

Text books 1. J. C. Berg, An Introduction to Interfaces and Colloids: The Bridge to Nanoscience, World Scientific, Singapore 2. P. Ghosh, Colloid and Interface Science, PHI Learning, New Delhi 3. R. J. Hunter, Foundations of Colloid Science, Oxford University Press, New York		
Reference books 1. D.J. Shaw, Colloid and Surface Chemistry, 4th Edition, Butterworth-Heinemann, Oxford 2. Myers, D. Surfaces, Interfaces, and Colloids: Principles and Applications. New York 3. Robert J. Stokes, D Fennell Evans, Fundamentals of Interfacial Engineering, Wiley-VCH 4. P. C. Hiemenz and R. Rajagopalan, Principles of Colloid and Surface Chemistry, Marcel Dekker, New York 5. Louis Theodore, A John, Nanotechnology: Basic Calculations for Engineers and Scientists – Willy & Sons 6. T. Pradeep, Nano-The Essentials, Understanding Nanoscience and Nanotechnology, 7. Kal Ranganathan Sharma, Nanostructuring Operations in NanoScale Science and Engineering, McGraw-Hill		
COURSE CONTENTS AND LECTURE SCHEDULE		
No.		No. of Hours
MODULE 1		
1.1	Introduction of Colloids	1
1.2	The colloidal state and classification	1
1.3	Importance of colloids	1
1.4	Properties and application of colloid systems	1
1.5	interaction between particles	1
1.6	colloid stability and aggregation	1
MODULE II		
2.1	Surfactants: classification, properties	1
2.2	applications	1
2.3	Surfactants in solution: micelles, vesicles	1

2.4	Micro emulsions Electrical phenomena at interfaces: Electric double layer	1
2.5	Micro emulsions Electrical phenomena at interfaces: Electric double layer	1
2.6	zeta potential	1
2.7	DLVO theory	1
MODULE III		
3.1	Surface free energy	1
3.2	films on liquid substrates (mono-molecular films, Langmuir-Blodgett layers)	1
3.3	films on liquid substrates (mono-molecular films, Langmuir-Blodgett layers)	1
3.4	Adsorption-Langmuir	1
3.5	Gibbs adsorption isotherm	1
3.6	Types of Interface	1
3.7	Types of Interface	1
3.8	Types of Interface	1
MODULE IV		
4.1	Flocculation, Coagulation	1
4.2	Electrokinetics, and Rheology of dispersions	1
4.3	Porous materials and membranes, Thin films	1
4.4	Thin films	1
4.5	Surfactant assisted nanoparticle synthesis	1
4.6	Applications of colloid and interfacial science	1
MODULE V		
5.1	Particle Size, Surface area, Volume, Equivalent Diameter	1
5.2	Particle Size, Surface area, Volume, Equivalent Diameter	1

5.3	Aerodynamic Diameter introduction	1
5.4	Measurement Methods – Microscopy, Optical Counter	1
5.5	Electrical Aerosol Analyzer, Bacho Microparticle classifier	1
5.6	Bacho Microparticle classifier	1
5.7	Particle Size analyzer, Volumetric flow rate	1
5.8	average particle concentration calculation	1
5.9	Volumetric flow rate and average particle concentration calculation	1

CO Assessment Sample Questions	
1	Explain colloidal stability.
2	Explain DLVO theory.
3	Explain the various surfactant assisted nanoparticle synthesis methods.
4	Explain the method of measurement of particle size diameter.

24CHE891	ENGINEERING OF CLIMATE CHANGE	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: This course provide a foundational understanding of the complexities of climate change engineering, focusing on global warming, sustainable energy solutions, and environmental policy. Through comprehensive modules, students will engage with topics such as climate change adaptation, mitigation strategies, and the role of engineering in addressing climate challenges.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Describe the climate change drivers and history.
CO2	Implement sustainable energy solutions for climate mitigation.
CO3	Evaluate global climate policies and agreements.
CO4	Apply environmental assessments for sustainable engineering.
CO5	Design cross-sector climate adaptation strategies.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2									
CO2	3	3		2								
CO3	3	3		3			3					
CO4	3	3			2		3					
CO5	3	3				3						

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyze			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3hrs

<u>End Semester Examination [ESE]: Pattern</u>

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I : Introduction to Climate Change Science(7 Hrs.)
Introduction: Weather and Climate, Components of the climate system and their interactions. Understanding Climate Change: Historical perspective, key contributors, and factors driving climate change. Climate Models: Introduction to climate modeling, types of climate models, and their applications in predicting climate change. Climate of India during the four seasons.
MODULE II : Global Warming and its Implications(7 Hrs.)
Greenhouse Effect: Principles and mechanisms, role of greenhouse gases, and impact on global temperatures. Global Warming Causes and Effects: Anthropogenic

and natural causes, impact on ecosystems, and implications for biodiversity. Carbon Footprint Analysis-Measurement techniques. Renewable energy technologies, carbon capture and storage, and sustainable practices for mitigating global warming.
MODULE III : Climate models (8 Hrs.)
One, two and 3-dimensional climate models, History of climate modelling, Sensitivity of climate models, parameterization of climate processes, interactions in the climate system. Application of climate model for prediction and policy development, future climate scenarios. Global warming and sea level rise, impacts of sea level rise, impact on fresh water sources, impact on natural ecosystems. International efforts to minimize climatic change and their impacts.
MODULE IV : Sustainable Energy Solutions (6 Hrs.)
Renewable Energy Technologies: Solar, wind, hydro, and geothermal energy technologies, their potential, and challenges in their deployment. Energy-efficient practices in industries, buildings, and transportation, energy audits, and optimizing energy consumption. Chemical engineering applications in developing sustainable energy solutions, current trends, and future prospects.
MODULE V : Environmental Policy and Climate Governance (8 Hrs.)
International Climate Agreements: Overview of major international agreements, their goals, and their impact on global climate change. Climate Governance: Role of governments, organizations, and stakeholders in climate governance, policy formulation, and implementation of climate change initiatives. Ethical and Social Considerations: Ethical dilemmas in climate change mitigation and adaptation, social equity, and justice in climate change policies and actions.

Text books 1. Climate Change: What Everyone Needs to Know by Joseph Romm 2. Fundamentals of Atmospheric Modelling, Marc Z. Jacobson, Cambridge University Press, 2005. 3. Adaptation and mitigation strategies for climate change, Sumi A., Fukushi and Ahiramatsu, Springer, 2010.
Reference books 1. Introduction to Modern Climate Change" by Andrew Dessler. 2. Global warming – the complete briefing (second edition): John Houghton, Cambridge university Press, 2009. 3. Energy Systems and Sustainability: Power for a Sustainable Future" by Bob Everett and Godfrey Boyle. 4. Climate Change Adaptation and Disaster Risk Reduction: An Asian Perspective" by Rajib Shaw. 5. Environmental Policy: New Directions for the Twenty-First Century" by Norman J. Vig and Michael E. Kraft.

COURSE CONTENTS AND LECTURE SCHEDULE		
No.		No. of Hours
MODULE 1		
1.1	Weather and Climate, Components of the climate system and their interactions.	1
1.2	Understanding Climate Change: Historical perspective, key contributors, and factors driving climate change.	1
1.3	Understanding Climate Change: Historical perspective, key contributors, and factors driving climate change	1
1.4	Climate Models: Introduction to climate modeling.	1
1.5	Types of climate models, and their applications in predicting climate change.	1
1.6	Types of climate models, and their applications in predicting climate change.	1
1.7	Climate of India during the four seasons.	1
MODULE II		

2.1	Principles and mechanisms, role of greenhouse gases, and impact on global temperatures.	1
2.2	Global Warming Causes and Effects	1
2.3	Anthropogenic and natural causes, impact on ecosystems, and implications for biodiversity	1
2.4	Anthropogenic and natural causes, impact on ecosystems, and implications for biodiversity	1
2.5	Carbon Footprint Analysis-Measurement techniques.	1
2.6	Renewable energy technologies.	1
2.7	Carbon capture and storage, and sustainable practices for mitigating global warming.	1
MODULE III		
3.1	One, two and 3-dimensional climate models, History of climate modelling	1
3.2	Sensitivity of climate models,	1
3.3	parameterization of climate processes, interactions in the climate system	1
3.4	Application of climate model for prediction and policy development, future climate scenarios.	1
3.5	Application of climate model for prediction and policy development, future climate scenarios.	1
3.6	Global warming and sea level rise, impacts of sea level rise, impact on fresh water sources, impact on natural ecosystems.	1
3.7	Global warming and sea level rise, impacts of sea level rise, impact on fresh water sources, impact on natural ecosystems.	1
3.6	International efforts to minimize climatic change and their impacts.	1
MODULE IV		
4.1	Renewable Energy Technologies: Solar, wind, hydro, and geothermal energy technologies, their potential, and challenges in their deployment.	1

4.2	Renewable Energy Technologies: Solar, wind, hydro, and geothermal energy technologies, their potential, and challenges in their deployment.	1
4.3	Energy-efficient practices in industries, buildings, and transportation.	1
4.4	Energy-efficient practices in industries, buildings, and transportation.	1
4.5	Energy audits, and optimizing energy consumption.	1
4.6	Chemical engineering applications in developing sustainable energy solutions, current trends, and future prospects.	1
	MODULE V	
5.1	International Climate Agreements: Overview of major international agreements, their goals, and their impact on global climate change.	1
5.2	International Climate Agreements: Overview of major international agreements, their goals, and their impact on global climate change.	1
5.3	Climate Governance: Role of governments, organizations, and stakeholders in climate governance	1
5.4	Climate Governance: Role of governments, organizations, and stakeholders in climate governance	1
5.5	Policy formulation, and implementation of climate change initiatives.	1
5.6	policy formulation, and implementation of climate change initiatives.	1
5.7	Ethical dilemmas in climate change mitigation and adaptation, social equity, and justice in climate change policies and actions.	1
5.8	Ethical dilemmas in climate change mitigation and adaptation, social equity, and justice in climate change policies and actions.	1

CO Assessment sample Questions	
1	Name the major contributors to climate change historically.
2	Develop a sustainable energy plan for a specific region considering its

	unique climate characteristics.

3	Analyze the impacts of climate change on specific ecosystems and biodiversity.
4	Evaluate the effectiveness of current climate change policies in a selected region.
5	Identify the key components of an effective climate change mitigation strategy.

EIGHTH SEMESTER

OPEN ELECTIVE-2

		L	T	P	J	S	C	Year of Introduction
24CHO812	WASTE TO ENERGY CONVERSION	3	0	0	0	3	3	2024

Preamble: This course aims to update the knowledge of students in the area of waste utilization for energy production through newer technologies. This course provides a comprehensive exploration of waste-to-energy conversion, covering waste characterization, energy production techniques (incineration, gasification, pyrolysis), biochemical and chemical routes, environmental aspects, biogas, plastic waste management, and innovations in energy production from solid wastes.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Characterize different types of waste behind waste-to-energy conversion processes.
CO2	Analyze the suitability of different waste-to-energy conversion methods for specific waste types.
CO3	Explain the properties of Biogas, plant technology and constructional features crucial for integrating biogas into sustainable bioenergy systems.
CO4	Explain various waste-to-energy techniques, through biochemical and chemical roots.
C05	Explain the principles and methodologies in harnessing energy from solid wastes.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO 9	PO10	PO11	PO12
CO1		1		2			3					
CO2		2		1			3					
CO3		1	2				3					
CO4		3		3			3					
CO5	2	2	3	3	1		3					

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔

Apply	✔	✔	✔	✔
Analyze			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 hr.

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I: Introduction to Energy from Waste

Introduction: Definition of wastes and their classification, Important quality parameters of different types of wastes, Waste suitable for energy production, Solid wastes and their classification, Wastewater and their classification. Need of energy production from wastes, present status of WTE technologies. Combustion: Nature and types of combustion processes – Mechanism.

MODULE II: Energy Production from Wastes
Energy Production from Wastes: Energy production through incineration, gasification, pyrolysis and syngas utilization. Incineration: principle, Incinerators parts and their types/working, Environmental impact and operational issues, advantages, and disadvantages; Gasification: principle, advantages, and disadvantages; Pyrolysis: principle, advantages, and disadvantages; Syngas utilization: principle, advantages, and disadvantages.
MODULE III: Energy production through biochemical and chemical routes

Energy production through biochemical and chemical routes- Energy production through anaerobic digestion, fermentation, transesterification and introduction to microbial fuel cells. Anaerobic digestion: principle, advantages, and disadvantages; Fermentation: principle, advantages, and disadvantages; Transesterification: principle, advantages, and disadvantages; Introduction to microbial fuel cells: principle, advantages, and disadvantages.
MODULE IV: Environmental Aspects and Biogas
Energy Production from Algae: Cultivation of algal biomass from wastewater and energy production from algae. Algae cultivation: principle, advantages, and disadvantages; Energy production from algae: principle, advantages, and disadvantages; Applications of algae in waste management. Biogas: Properties of biogas (Calorific value and composition) - Biogas plant technology and status - Bio energy system - Design and constructional features
MODULE V: Energy Production from Solid Wastes
Energy Production from Solid Wastes: Densification of solids, efficiency improvement of power plant and energy production from waste plastics. Densification of solids: principle, advantages, and disadvantages; Efficiency improvement of power plants: principle, advantages, and disadvantages; Energy production from waste plastics: principle, advantages, and disadvantages; Applications of waste plastics in energy generation.
Text books 1. Rogoff, M. J. and Screve, F., "Waste-to-Energy: Technologies and Project Implementation", Elsevier Store, 2011. 2. Young G. C., "Municipal Solid Waste to Energy Conversion processes", John Wiley and Sons, 2010. 3. Harker, J. H. and Backhusrt, J. R., "Fuel and Energy", Academic Press Inc, 1981. 4. EL-Halwagi, M. M., "Biogas Technology – Transfer and Diffusion", Elsevier Applied Science, 1986. 5. Hall, D.O. and Overeed, R.P.," Biomass – Renewable Energy", John Willy and Sons. Mondal, P. and Dalai, A. K. eds., 2017. Sustainable

Utilization of Natural Resources. CRC Press.
Reference books 1. Food, Feed and Fuel from Biomass, Challal, D. S., IBH Publishing Co. Pvt. Ltd., 1991. 2. Biomass Conversion and Technology, C. Y. WereKo-Brobby and E. B. Hagan, John Wiley & Sons, 1996

COURSE CONTENTS AND LECTURE SCHEDULE		
No.		No. of Hours
MODULE 1 (7 hours)		
1.1	Introduction: Definition of wastes and their classification, Important quality parameters of different types of wastes.	1
1.2	Waste suitable for energy production, Solid wastes and their classification, Wastewater and their classification	1
1.3	Need of energy production from wastes, present status of WTE technologies.	1
1.4	Characterization of solid wastes: Physical, Chemical, Proximate and ultimate analysis.	1
1.5	Fusing point of ash, Lignocellulosic composition, Leaching properties, energy content: Heating value.	1
1.6	Fusing point of ash, Lignocellulosic composition, Leaching properties, energy content: Heating value.	1
1.7	Characterization of wastewater. Combustion: Nature and types of combustion processes – Mechanism.	1
MODULE II (7 hours)		

2.1	Energy Production from Wastes: Energy production through incineration, gasification, pyrolysis and syngas utilization.	1
2.2	Energy Production from Wastes: Energy production through incineration, gasification, pyrolysis and syngas utilization.	1
2.3	Incineration: principle, Incinerators parts and their types/working.	1
2.4	Environmental impact and operational issues, advantages, and disadvantages.	1
2.5	Gasification: principle, advantages, and disadvantages.	1
2.6	Pyrolysis: principle, advantages, and disadvantages.	1
2.7	Syngas utilization: principle, advantages, and disadvantages.	1
MODULE III (8 hours)		
3.1	Biomass Gasification: Gasifiers – Fixed bed system – Downdraft and updraft gasifiers.	1
3.2	Biomass Gasification: Gasifiers – Fixed bed system – Downdraft and updraft gasifiers.	1
3.3	Fluidized bed gasifiers – Design, construction and operation.	1
3.4	Energy production through biochemical and chemical routes	1
3.5	Energy production through anaerobic digestion, fermentation, transesterification and introduction to microbial fuel cells	1
3.6	Anaerobic digestion: principle, advantages, and disadvantages;	1
3.7	Fermentation: principle, advantages, and disadvantages	1

3.8	Transesterification: principle, advantages, and disadvantages; Introduction to microbial fuel cells: principle, advantages, and disadvantages.	1
MODULE IV (7 hours)		
4.1	Definition of pyrolysis, mechanism, Types of pyrolysis.	1
4.2	Operating conditions and end product distribution.	1

4.3	Options for management of plastic wastes and recycling through pyrolysis.	1
4.4	Energy Production from Algae: Cultivation of algal biomass from wastewater and energy production from algae.	1
4.5	Algae cultivation: principle, advantages, and disadvantages.	1
4.6	Energy production from algae: principle, advantages, and disadvantages.	1
4.7	Applications of algae in waste management.	1
MODULE V (7 hours)		
5.1	Energy Production from Solid Wastes: Densification of solids, efficiency improvement of power plant and energy production from waste plastics.	1
5.2	Energy Production from Solid Wastes: Densification of solids, efficiency improvement of power plant and energy production from waste plastics.	1
5.3	Densification of solids: principle, advantages, and disadvantages.	1
5.4	Efficiency improvement of power plants: principle, advantages, and disadvantages.	1
5.5	Energy production from waste plastics: principle, advantages, and disadvantages.	1
5.6	Energy production from waste plastics: principle, advantages, and disadvantages.	1
5.7	Applications of waste plastics in energy generation.	1

CO Assessment Sample Questions	
CO1	Imagine you are tasked with developing a waste-to-energy system for a city. How would you categorize and characterize the different types of waste to optimize energy production?

CO2	Compare and contrast the suitability of incineration and gasification for different types of waste.
CO3	Describe the properties of biogas and its significance in sustainable bioenergy systems.
CO4	Compare the environmentalimpacts of incineration and anaerobic digestion in waste-to-energy processes.
CO5	Explain the potential environmental impacts associated with inefficient waste-to-energy processes. Explain how adopting densification and improving power plant efficiency can mitigate these impacts

24CHO822	INDUSTRIAL WASTE MANAGEMENT	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: This course provides students with essential skills and knowledge for effective industrial waste management. It covers diverse topics, including types of industries, waste treatment techniques, and the impact of industrial effluents on the environment and human health. Additionally, the syllabus emphasizes cleaner production methods, pollution control, treatment technologies, and hazardous waste management practices.

Prerequisite: Nil.

Course Outcomes: After the completion of the course the student will be able to

CO1	Explain the different types of industries and their respective pollution characteristics.
CO2	Apply cleaner production principles, conduct waste audits, and implement strategies for volume and strength reduction of industrial waste.
CO3	Analyze and characterize specific pollution sources and attributes associated with major industries.
CO4	Implement various treatment technologies such as equalization, neutralization, and chemical oxidation.
CO5	Identify and classify hazardous waste materials and disposal methods.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO 9	PO10	PO11	PO12
CO1	3	3				3	3					
CO2	3	3				3	3					
CO3	3	3				3	3					
CO4	3	3				3	3					
CO5	3	3				3	3					

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔

Analyse			✔	
Evaluate			✔	
Create			✔	
Mark Distribution of CIA				

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 Hrs.
End Semester Examination [ESE]: Pattern			

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS
MODULE I : INTRODUCTION to WASTE AND REGULATIONS (8 Hrs.)
Types of industries and industrial pollution – Characteristics of industrial wastes – Population equivalent – Bioassay studies – effects of industrial effluents on streams, sewer, land, sewage treatment plants and human health – Environmental legislations related to prevention and control of industrial effluents and hazardous wastes.

MODULE II : CLEANER PRODUCTION (7 Hrs.)
Waste management Approach – Waste Audit – Volume and strength reduction – Material and process modifications – Recycle, reuse and byproduct recovery – Applications.
MODULE III : POLLUTION FROM MAJOR INDUSTRIES (8 Hrs.)
Sources, Characteristics, waste treatment flow sheets for selected industries such as Textiles, Tanneries, Pharmaceuticals, Electroplating industries, Dairy, Sugar, Paper, distilleries, Steel plants, Refineries, fertilizer, thermal power plants – Wastewater reclamation concepts.

MODULE IV : TREATMENT TECHNOLOGIES (8 Hrs.)
Equalization – Neutralization – Removal of suspended and dissolved organic solids - Chemical oxidation – Adsorption - Removal of dissolved inorganics – Combined treatment of industrial and municipal wastes – Residue management – Dewatering – Disposal.
MODULE V : HAZARDOUS WASTE MANAGEMENT (5 Hrs.)
Hazardous wastes - Physio chemical treatment – solidification – incineration – Secure landfills.
Text books 1. M.N.Rao & A.K.Dutta, "Wastewater Treatment", Oxford - IBH Publication, 1995. 2. W .W. Eckenfelder Jr., "Industrial Water Pollution Control", McGraw-Hill Book Company, New Delhi, 2000.
Reference books 1. T.T.Shen, "Industrial Pollution Prevention", Springer, 1999. 2. R.L.Stephenson and J.B.Blackburn, Jr., "Industrial Wastewater Systems Hand book", Lewis Publisher, New Yark, 1998. 3. H.M.Freeman, "Industrial Pollution Prevention Hand Book", McGraw-Hill Inc., New Delhi, 1995. 4. Bishop, P.L., "Pollution Prevention: Fundamental & Practice", McGraw-Hill, 2000.

COURSE CONTENTS AND LECTURE SCHEDULE		
No.		No. of Hours
	MODULE 1	
1.1	Types of industries and industrial pollution.	1
1.2	Characteristics of industrial wastes.	1

1.3	Population equivalent, Bioassay studies.	1
1.4	Effects of industrial effluents on various environmental components.	1
1.5	Effects of industrial effluents on various environmental components.	1
1.6	Environmental legislations related to prevention and control of industrial effluents and hazardous wastes.	1
1.7	Environmental legislations related to prevention and control of industrial effluents and hazardous wastes.	1
1.8	Environmental legislations related to prevention and control of industrial effluents and hazardous wastes.	1
	MODULE II	
2.1	Waste management Approach, Waste Audit.	1
2.2	Waste management Approach, Waste Audit.	1
2.3	Volume and strength reduction.	1
2.4	Material and process modification.	1
2.5	Material and process modification.	1
2.6	Recycle, reuse and byproduct recovery – Applications.	1
2.7	Recycle, reuse and byproduct recovery – Applications.	1
	MODULE III	
3.1	Sources, characteristics.	1
3.2	Waste treatment flow sheets for selected industries such as Textiles, Tanneries.	1
3.3	Waste treatment flow sheets for selected industries such as Textiles, Tanneries.	1
3.4	Waste treatment flow sheets for selected industries such as Pharmaceuticals, Electroplating industries, Dairy, Sugar, Paper, distilleries.	1
3.5	Waste treatment flow sheets for selected industries such as Steel plants, Refineries, fertilizer, thermal power plants.	1
3.6	Waste treatment flow sheets for selected industries such as Steel plants, Refineries, fertilizer, thermal power plants.	1
3.5	Wastewater reclamation concepts.	1

MODULE IV		
4.1	Equalization, neutralization.	1
4.2	Removal of suspended and dissolved organic solids.	1
4.3	Chemical oxidation , Adsorption , Removal of dissolved inorganics.	1
4.4	Chemical oxidation , Adsorption , Removal of dissolved inorganics	1
4.5	Combined treatment of industrial and municipal wastes.	1
4.6	Combined treatment of industrial and municipal wastes.	1
4.7	Residue management , Dewatering, Disposal.	1
4.8	Residue management , Dewatering, Disposal.	1
MODULE V		
5.1	Hazardous wastes.	1
5.2	Physio chemical treatment.	1
5.3	Solidification.	1
5.4	Incineration.	1
5.5	Secure landfills.	1

CO Assessment sample Questions	
1	List the main types of industries contributing to pollution and their associated pollutants.
2	Create a plan to reduce industrial waste volume and strength in a specific industry using cleaner production principles.
3	Describe the pollution sources and impacts of the textile industry's effluents.
4	Assess the effectiveness of equalization in wastewater treatment across different industrial settings.
5	List the key characteristics used to classify hazardous waste.

		L	T	P	J	S	C	Year of Introduction
24CHO832	ENERGY TECHNOLOGY AND ENERGY MANAGEMENT	3	0	0	0	3	3	2024

Preamble: This course provides basic knowledge on various energy resources,
conversion processes and energy management. Students may gain knowledge on Energy Auditing, Energy conservation, Waste Heat Recovery, Maintenance of Energy Systems.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Identify and explain energy resources and energy conversion processes
CO2	Explain energy conversion from solar, ocean and wind energy.
CO3	Explain energy conversion from biomass and fuel cells
CO4	Explain energy policies, energy management and audit.
CO5	Apply the energy conservation methods in various fields of chemical process industries, commercial and residential buildings.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1						3	2					
CO2						3	2					
CO3						3	2					
CO4						3	2					
CO5						3	2					

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test 1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyze			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	

3-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I : Introduction to Energy Conversion (7 Hrs.)

Energy resources, Energy conversion processes and devices – Energy conversion plants – Conventional - Thermal, Hydro, Nuclear fission , and non – conventional – Solar -Wind- BiomassFuel cells- Magneto Hydrodynamics and Nuclear fusion.
Energy from waste, Energy plantation.

MODULE II : Non-conventional energy sources (7 Hrs.)

Solar energy- Solar thermal systems- Flat plate collectors- Focusing collectors- Applications of solar energy in India - Instruments to measure solar radiation- Pyranometer – Pyrheliometer. Ocean wave energy conversion- Ocean thermal energy conversion- Tidal energy conversion- Wind energy- Types of windmills- Wind electric power generation- Wind power in India.

MODULE III : Biomass energy resources (7 Hrs.)

Thermochemical and Biochemical methods of biomass conversion, Fuel cells- Alkaline fuel cell Phosphoric acid fuel cell- Molten carbonate fuel cell, Solid oxide fuel cell- Solid polymer electrolyte fuel cell, Basic concepts of Microbial fuel cell.
MODULE IV : Energy management and Energy audit (7 Hrs.)
Energy Scenario – Global and Indian –Impact of Energy on economy, development and environment, Energy policies. Energy Management – Definitions and significance – Objectives – Characterizing of energy usage – Energy Management program – Energy strategies and energy planning. Energy Audit – Types and Procedure – Optimum performance of existing facilities – Energy management

control systems – Computer applications in energy management.
MODULE V : Energy conservation (7 Hrs.)
Energy conservation – Principles – Energy conservation technologies – Cogeneration – Waste heat recovery – Combined cycle power generation – Energy Conservation Opportunities – Electrical ECOs – Thermodynamic ECOs in chemical process industry – ECOs in residential and commercial buildings – Energy Conservation Measures.
Text books 1. Rao S. & Parulekar B.B., Energy Technology, Khanna Publishers. 2. Bansal N.K., Kleeman M. & Meliss M., Renewable Energy Sources & Conversion Tech.,Tata McGraw Hill. 3. Goldmberg J., Johansson, Reddy A.K.N. & Williams R.H., Energy for a Sustainable World, John Wiley. 4. Amlan Chakrabarti, Energy Engineering and Management, Prentice Hall India, 2011. CHEMICAL ENGINEERING. 5. Eastop T. D. and D. R. Croft, Energy Efficiency for Engineers & Technologists, Longman, 1990.
Reference books 1. Sukhatme S.P., Solar Energy, Tata McGraw Hill. 2. Mittal K.M., Non-Conventional Energy Systems, Wheeler Publications. 3. Venkataswarlu D.I, Chemical Technology, S. Chand. 4. Pandey G.N., A Text Book on Energy System and Engineering, Vikas Publishing. 5. Rai G.D., Non-Conventional Energy Sources, Khanna Publishers. 6. S.S.Thipse, Energy conservation and management, Narosa Publishing House 7. Albert Thumann P. E. and W. J. Younger, Handbook of Energy Audits, Fairmont Press, 2008.

COURSE CONTENTS AND LECTURE SCHEDULE		
No.		No. of Hours
MODULE 1		
1.1	Energy resources, Energy conversion processes and devices	1
1.2	Energy conversion plants – Conventional - Thermal, Hydro, Nuclear fission	1
1.3	Energy conversion plants – Conventional - Thermal, Hydro, Nuclear fission	1
1.4	Energy conversion plants – Non – conventional – Solar - Wind- Biomass Fuel cells-	1
1.5	Energy conversion plants –Magneto Hydrodynamics and Nuclear fusion.	1
1.6	Energy conversion plants –Magneto Hydrodynamics and Nuclear fusion.	1
1.7	Energy from waste, Energy plantation.	1
MODULE II		
2.1	Solar energy- Solar thermal systems- Flat plate collectors- Focusing collectors- Applications of solar energy in India.	1
2.2	Solar energy- Solar thermal systems- Flat plate collectors- Focusing collectors- Applications of solar energy in India.	1
2.3	Instruments to measure solar radiation- Pyranometer – Pyrheliometer	1
2.4	Ocean wave energy conversion- Ocean thermal energy conversion- Tidal energy conversion-	1
2.5	Ocean wave energy conversion- Ocean thermal energy conversion- Tidal energy conversion-	1
2.6	Wind energy- Types of windmills	1
2.7	Wind electric power generation- Wind power in India	1
MODULE III		
3.1	Biomass energy resources- Thermochemical and Biochemical methods of biomass conversion.	1
3.2	Biomass energy resources- Thermochemical and Biochemical methods of biomass conversion.	1
3.3	-Fuel cells- Alkaline fuel cell- Phosphoric acid fuel cell	1

3.4	-Fuel cells- Alkaline fuel cell- Phosphoric acid fuel cell	1
3.5	Molten carbonate fuel cell, Solid oxide fuel cell.	1
3.6	Solid polymer electrolyte fuel cell	1
3.7	Basic concepts of Microbial fuel cell	1
	MODULE IV	
4.1	Energy Scenario – Global and Indian –Impact of Energy on economy, development and environment.	1
4.2	Energy Management – Definitions and significance – Objectives	1
4.3	Characterizing of energy usage – Energy Management program	1
4.4	energy policies. – Energy strategies and energy planning.	1
4.5	Energy Audit – Types and Procedure – Optimum performance of existing facilities	1
4.6	Energy Audit – Types and Procedure – Optimum performance of existing facilities	1
4.7	Energy management control systems – Computer applications in energy management.	1
	MODULE V	
5.1	Energy conservation – Principles -Energy conservation technologies – Cogeneration	1
5.2	Energy conservation – Principles -Energy conservation technologies – Cogeneration	1
5.3	Waste heat recovery – Combined cycle power generation	1
5.4	Energy Conservation Opportunities – Electrical ECOs	1
5.5	Thermodynamic ECOs in chemical process industry	1
5.6	ECOs in residential and commercial buildings	1
5.7	Energy Conservation Measures	1

CO Assessment sample Questions	
1	List out the energy conversion devices.
2	Explain energy conversion from solar, ocean and wind energy
3	Describe the energy conversion methods from biomass
4	What are the energy policies employed in India?
5	Discuss the use of cogeneration as an energy conservation tool
6	Describe with a neat diagram on waste heat recovery in industries.

EIGHTH SEMESTER

OPEN ELECTIVE-3

24CHO813	Petroleum Resources and Petrochemicals	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble:
This course provides the concepts of petroleum refinery operations that are relevant and used for applications in chemical engineering. This course summarizes preliminary, primary and secondary petroleum refinery operations. It also explains the classification and evaluation of crude oil and outlines the manufacturing process of petroleum products.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Explain various petroleum resources and their origin.
CO2	Outline the process employed in exploration and drilling.
CO3	Explain the preliminary processes in petroleum refining.
CO4	Explain various thermal conversion processes in petroleum refining.
CO5	Describe the manufacturing process of various petrochemical products.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2				1	1					1
CO2	3	2				1	1					1
CO3	3	2				1	1					1
CO4	3	2				1	1					1
CO5	3	2				1	1					1

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 hr.

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS
MODULE I : Introduction to petroleum industry
Overview of Oil and Gas Resources, Origin and formation of crude oil. Basic Review of Petroleum Geology, The Geologic Column, Petroleum Traps, Migration and Accumulation.
MODULE II : Exploration and drilling
Oil exploration and drilling, Basic Functions and Components of Rig, Drilling Fluid Functions, Types and Compositions, Fundamental Drilling Operations. Classification, Composition and Evaluation of oil stock.
MODULE III : Preliminary petroleum processing
Preliminary petroleum processing -Impurities in crude oil, Dehydration and desalting of crude-Electric Desalter-, Process description, factors affecting the electric desalter. Distillation of crude- Prefractionator, Atmospheric topping unit, Vacuum distillation unit.
MODULE IV : Conversion operations
Thermal Conversion process: Process description of Thermal cracking, Visbreaking, Coking (delayed coking). Process description of catalytic cracking, Process description of Fluid Catalytic cracking unit. Process description of Hydro cracking. Process description of catalytic reforming.
MODULE V : Petrochemicals

Classification of petrochemicals: light, medium and heavy. Manufacture of Methanol from Synthesis Gas, manufacture of formaldehyde from methanol, manufacture of Low-density polyethylene(LDPE) and high density polyethylene(HDPE). Manufacture of Benzene, toluene, Toluene and Xylene by catalytic reforming. Manufacture of Isopropanol from propylene [Flow sheets not required]
Text books 1. Baskara Rao B.K, Modern Petroleum Refinery Process, Oxford & IBM 2. Dr.Ram Prasad, Petroleum Refining Technology, Khanna Publishers 3. Dryden C. E., Outlines of Chemical Technology, East-West Press, 2008 4. M. Wells, Handbook of Petrochemicals and Processes, 2nd Ed., Ashgate Publishing Co., 1999.
Reference books 1. Uttam Ray Chaudhuri, Fundamentals of Petroleum and Petrochemical Engineering, CRC Press 2. Dr.Kochu Baby Manjooran S, Modern Petroleum Chemistry 3. James H.Garry Glenn E. Handwerk Mark J.Kaiser, Petroleum Refinery Technology and Economics, CRC Press, Taylor and Francis group. 4. I D Mall, Petrochemical Process technology, Macmillan 5. Nelson W.L, Petroleum Refinery Engineering, McGraw Hill 6. Gopala Rao M & Sitting M, Drydens Outline of Chemical Technology, Affiliated East West Press

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
	MODULE 1 (6 hours)	
1.1	Overview of Oil and Gas Resources	1
1.2	Origin and formation of crude oil.	1
1.3	Basic Review of Petroleum Geology, The Geologic Column.	1
1.4	Petroleum Traps.	1
1.5	Migration and Accumulation.	1
1.6	Migration and Accumulation.	1
	MODULE II (7 hours)	
2.1	Basic Functions and Components of Rig.	1

2.2	Drilling Fluid Functions.	1
2.3	Types and Compositions.	1
2.4	Fundamental Drilling Operations.	1
2.5	Classification and Composition of oil stock.	1
2.6	Evaluation oil stock.	1
2.7	Evaluation oil stock.	1
MODULE III (7 hours)		
3.1	Impurities in crude oil.	1
3.2	Dehydration and desalting of crude-Electric Desalter.	1
3.3	Dehydration and desalting of crude-Electric Desalter.	1
3.4	Process description, factors affecting the electric desalter.	1
3.5	Distillation of crude- Prefractionator.	1
3.6	Distillation of crude- Atmospheric topping unit.	1
3.7	Distillation of crude- Vacuum distillation unit.	1
MODULE IV (8 hours)		
4.1	Thermal Conversion process: Process description of Thermal cracking.	1
4.2	Process description of Visbreaking.	1
4.3	Process description of Coking (delayed coking).	1
4.4	Process description of catalytic cracking.	1
4.5	Process description of Fluid Catalytic cracking unit.	1
4.6	Process description of Hydro cracking.	1

4.7	Process description of catalytic reforming.	1
4.8	Process description of catalytic reforming.	1

MODULE V (8 hours)		
5.1	Classification of petrochemicals: light , medium and heavy.	1
5.2	Manufacturing process of Methanol from Synthesis Gas.	1
5.3	Manufacturing process formaldehyde from methanol.	1
5.4	Manufacturing process of Low-density polyethylene(LDPE).	1
5.5	Manufacturing process of high-density polyethylene(HDPE).	1
5.6	Manufacturing process of Benzene, toluene, Toluene and Xylene by catalytic reforming.	1
5.7	Manufacturing process of Isopropanol from propylene.	1
5.8	Manufacturing process of Acrylonitrile by propylene ammonia air oxidation process.	1

CO Assessment sample Questions	
1	Explain the organic theory of formation of petroleum.
2	Enumerate and explain the functions of drilling fluid.
3	Explain atmospheric distillation of crude oil with a simplified flow diagram.
4	A chemical process is used to convert straight run naphtha distilled from crude oil into high octane liquid products which are premium blending stocks for high octane gasoline. Explain the process with a neat sketch and mention the catalysts used.
5	Explain the manufacture of Methanol from Synthesis Gas.

24CHO823	Pollution Control in Process Industries	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: This course is an overview of the industrial waste treatment and disposal
as used in the twentieth century and how it is evolving into a new conceptual field during the twenty-first century. The major topics covered are types of industrial pollution such as wastewater, hazardous waste, air pollution and its various treatment methods to abate the pollution level in the environment.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Outline the Industrial environmental history and various strategies for pollution abatement.
CO2	Summarize various unit operations and process for the removal of inorganic contaminations from industrial effluent
CO3	Describe the principle and working of various biological treatment systems for stabilization of organic fractions in industrial effluent.
CO4	Identify the sources of hazardous and toxic wastes from industries and their treatment methods.
CO5	Illustrate air contaminants from process industries and develop strategies for zero pollution.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3					3	3					2
CO2	3					3	3					2
CO3	3					3	3					2
CO4	3					3	3					2
CO5	3					3	3					2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyze			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA					
Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Mark distribution			
Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 Hours

<u>End Semester Examination [ESE]: Pattern</u>

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks: [5x8 = 40 marks]	

SYLLABUS

MODULE I : Industrial environmental history and pollution abatement

Industrial environmental history, Introduction to industrial waste treatment, Theories and practices: Volume Reduction, Classification of Wastes, Conservation of Wastewater, Examination of Batch or Slug Discharges of Process Wastes.

Contaminant concentration reduction: process changes; equipment modifications; segregation of wastes; equalization of wastes; by-product recovery; proportioning
wastes; monitoring waste streams.Neutralization, Equalization and proportioning.

MODULE II : Inorganic Fraction Removal

Removal of suspended solids: Sedimentation, Floatation and Screening

Removal of colloidal solids: Characteristics of Colloids, Chemical Coagulation, Coagulation by Neutralization of Electrical Charges, Removal of Colloids by Adsorption

Removal of inorganic dissolved solids: Evaporation, Dialysis, Ion Exchange, Algae,

Reverse Osmosis, Miscellaneous Methods

MODULE III : Biological Methods for Organic Fractions Removal

Removal of organic dissolved solids: lagooning in oxidation ponds; activated-sludge

treatment; modified aeration; dispersed-growth aeration; contact stabilization; high-rate aerobic treatment (total oxidation); trickling filtration; spray irrigation; wet combustion; anaerobic digestion; mechanical aeration system; deep-well injection; foam phase separation; brush aeration; subsurface disposal; Bio-Disc system.

Treatment and disposal of sludge solids: anaerobic and aerobic digestion; vacuum

filtration; elutriation; drying beds; sludge lagooning; wet combustion; atomized

suspension; drying and incineration; centrifuging; sludge barging; landfill

MODULE IV : Hazardous and Toxic Waste Treatment

Joint treatment of raw industrial waste with domestic sewage.

Hazardous wastes: Effects on Environment, Classification- Ignitable Hazardous Wastes, Corrosive Hazardous Wastes- Oil Refinery Sludges Toxic Industrial Wastes-Mercury-Containing Wastes, Metal-Containing Sludge Acute Hazardous Industrial Wastes- Radioactive Wastes, Hospital Wastes.

Storage of Hazardous Industrial Wastes.

MODULE V : Air Contaminants and Zero Pollution

Removal of industrial air contaminants: Theories and Practices of Suspended and gaseous particle removal.

Procedure for Industry in Attaining Zero Pollution: environmentally balanced industrial complex (EBIC)

Associated steps must be considered

Realistic Implementation of the EBIC System

Text books

1. Nelson Leonard Nemerow - Industrial waste treatment _ [contemporary practice and vision for the future]-Elsevier_Butterworth-Heinemann (2007)
2. Nicholas P. Cheremisinoff, Handbook of Water and Wastewater Treatment technologies, Butterworth-Heinemann (2001)
3. Frank Woodard - Industrial Waste Treatment Handbook-Butterworth-Heinemann

(2001).
Reference books 1. Rao C.S., Environmental Pollution Control Engineering, New age International Pub. 2. Metcalf & Eddy, Wastewater Engineering: Treatment, Disposal and Reuse, McGraw Hill, 2005. 3. Peavy, H.S., Rowe, D.R. and Tchobanoglous, G., Environmental Engineering, McGraw-Hill. 4. Mahajan S.P., Pollution Control in Process Industries, Tata McGraw-Hill.

COURSE CONTENTS AND LECTURE SCHEDULE		
No.		No. of Hours
MODULE 1 (9 hours)		
1.1	Industrial environmental history, Introduction to industrial waste treatment	1
1.2	Theories and practices: Volume Reduction, Classification of Wastes, Conservation of Wastewater	1
1.3	Examination of Batch or Slug Discharges of Process Wastes	1
1.4	Contaminant concentration reduction: process changes	1
1.5	equipment modifications; segregation of wastes	1
1.6	equalization of wastes, by-product recovery	1
1.7	proportioning wastes; monitoring waste streams.	1
1.8	Neutralization, Equalization and proportioning	1
1.9	Neutralization, Equalization and proportioning	1
MODULE II (7 hours)		
2.1	Removal of suspended solids: Sedimentation, Floatation and Screening	1

2.2	Removal of colloidal solids: Characteristics of Colloids, Chemical Coagulation, Coagulation by Neutralization of Electrical Charges	1
2.3	Removal of Colloids by Adsorption	1
2.4	Removal of inorganic dissolved solids: Evaporation	1
2.5	Dialysis, Ion Exchange	1
2.6	Algae, Reverse Osmosis, Miscellaneous Methods	1
2.7	Algae, Reverse Osmosis, Miscellaneous Methods	1
MODULE III (9 hours)		
3.1	Removal of organic dissolved solids: lagooning in oxidation ponds	1
3.2	activated-sludge treatment; modified aeration; dispersed-growth aeration; contact stabilization;	1
3.3	high-rate aerobic treatment (total oxidation); trickling filtration; spray irrigation; wet combustion	1
3.4	anaerobic digestion; mechanical aeration system	1
3.5	deep-well injection; foam phase separation; brush aeration; subsurface disposal; Bio-Disc system.	1
3.6	Treatment and disposal of sludge solids: anaerobic and aerobic digestion	1
3.7	vacuum filtration; elutriation; drying beds	1
3.8	sludge lagoon Ing; wet combustion; atomized suspension; drying and incineration	1
3.9	centrifuging; sludge barging; landfill	1
MODULE IV (6 hours)		

4.1	Joint treatment of raw industrial waste with domestic sewage.	1
4.2	Hazardous wastes: Effects on Environment, Classification- Ignitable Hazardous Wastes	1

4.3	Corrosive Hazardous Wastes- Oil Refinery Sludges	1
4.4	Toxic Industrial Wastes-Mercury-Containing Wastes, Metal-Containing Sludge	1
4.5	Acute Hazardous Industrial Wastes- Radioactive Wastes, Hospital Wastes	1
4.6	Storage of Hazardous Industrial Wastes	1
MODULE V (5 hours)		
5.1	Removal of industrial air contaminants: Theories and Practices of Suspended Particle and gaseous pollutant Removal.	1
5.2	Theories and Practices of Suspended Particle and gaseous pollutant Removal.	1
5.3	Procedure for Industry in Attaining Zero Pollution: environmentally balanced industrial complex (EBIC)	1
5.4	Associated steps must be considered	1
5.5	Realistic Implementation of the EBIC System	1

CO Assessment sample Questions	
1	Describe the methods for reducing the wastewater generation in process industries.
2	With a neat sketch, explain the principle and working of multiple effect evaporator in effluent treatment.
3	Explain the mechanism of sludge stabilization using two stage anaerobic sludge digester.
4	List the classification of hazardous wastes with examples. Describe the standard methods for the disposal of hazardous wastes from industrial sources.
5	Describe the steps associated to attain environmentally balanced industrial complex for process industries.

24CHO833	HYDROGEN ENERGY TECHNOLOGY	L	T	P	J	S	C	Year of Introduction
		3	0	0	0	3	3	2024

Preamble: The course will comprehensively cover all the aspects of the hydrogen energy value chain including production methods, storage, utilization in various sectors, associated energy conversion devices, sensing and safety. The course will provide a broad knowledge of hydrogen as an energy carrier.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Explain the basic nature of hydrogen as a fuel
CO2	Explain the various hydrogen production processes
CO3	Explain the various methods of storage of hydrogen
CO4	Explain the thermodynamics of fuel cells

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3									
CO2	3	3										
CO3	3	3	3									
CO4	3	3	3									

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test2	Other tools	
Remember	✔	✔	✔	✔
Understand	✔	✔	✔	✔
Apply	✔	✔	✔	✔
Analyse			✔	
Evaluate			✔	
Create			✔	

Mark Distribution of CIA

Course Structure [L-T-P-J]	Attendance	Theory [L- T]			Total Marks
		Assignment	Test-1	Test-2	
3-0-0-0	5	15	10	10	40

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	3 HOURS

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	10 Questions, each question carries 2 marks Marks: (2x10 =20 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 sub divisions. Each question carries 8 marks. Marks: (5x8 = 40 marks) Time: 3 hours	60
	Total Marks: 20	Total Marks [5x8 = 40 marks:]	

SYLLABUS
MODULE I : Introduction to hydrogen energy systems (7 hours)
Properties of hydrogen as fuel, Hydrogen pathways introduction-current uses, general introduction to infrastructure requirement for hydrogen production, storage, dispensing and utilization, and hydrogen production plants
MODULE II : Hydrogen production processes (7 hours)
Thermal-Steam reformation, thermo chemical water splitting, gasification-pyrolysis, nuclear thermal catalytic and partial oxidation methods. Electrochemical Electrolysis, photo electro chemical method.
MODULE III : Hydrogen storage and safety (8 hours)
Physical and chemical properties, general storage methods, compressed storage-composite cylinders, metal hydride storage, carbon based materials for hydrogen storage. Hydrogen safety aspects, backfire, pre-ignition, hydrogen emission NOx control techniques and strategies, Hydrogen powered vehicles
MODULE IV : Fuel cells (8 hours)
Basic principle of direct energy conversion using fuel cells; Thermodynamics of fuel cells Fuel cell types: AFC, PEMFC, MCFC, SOFC, Microbial Fuel cell
MODULE V : Applications of fuel cells (6 hours)

Fuel cell usage for domestic power systems, large scale power generation, automobile, space applications, economic and environmental analysis on usage of fuel cell, future trends of fuel cells
Text books 1. EG&G Technical Services, Fuel Cell Handbook, Morgantown, West Virginia, USA , 2004 2. Peter Hoffman, Tomorrow's Energy: Hydrogen, Fuel cells and the prospects for a cleaner planet, MIT Press, Cambridge, London, England , 2001 3. Gupta, R. B., Hydrogen Fuel: Production, Transport and Storage, CRC Press, Taylor & Francis Group, 2009.

4. Agata Godula-Jopek, Hydrogen Production by Electrolysis, Wiley-VCH, Germany, 2015
Reference books 1. Chris Rayment and Scott Sherwin,, Introduction to Fuel Cell Technology, Notre Dame, U.S.A , 2003

COURSE CONTENTS AND LECTURE SCHEDULE

No.		No. of Hours
MODULE 1		
1.1	Introduction of hydrogen energy systems	1
1.2	Properties of hydrogen as fuel	1
1.3	Hydrogen pathways introduction-current uses	1
1.4	general introduction to infrastructure requirement for hydrogen production	1
1.5	storage, dispensing and utilization	1
1.6	hydrogen production plants	1
1.7	hydrogen production plants	1
MODULE II		
2.1	Thermal-Steam reformation	1
2.2	thermo chemical water splitting	1
2.3	gasification-pyrolysis	1

2.4	nuclear thermal catalytic	1
2.5	partial oxidation methods	1
2.6	Electrochemical Electrolysis, photo electro chemical method	1
2.7	Electrochemical Electrolysis, photo electro chemical method	1
MODULE III		
3.1	Physical and chemical properties	1
3.2	general storage methods	1
3.3	compressed storage-composite cylinders	1
3.4	metal hydride storage, carbon based materials for hydrogen storage	1
3.5	metal hydride storage, carbon based materials for hydrogen storage	1
3.6	Hydrogen safety aspects, backfire, pre-ignition	1
3.7	hydrogen emission NOx control techniques and strategies, Hydrogen powered vehicles	1
3.8	hydrogen emission NOx control techniques and strategies, Hydrogen powered vehicles	1
MODULE IV		
4.1	Basic principle of direct energy conversion using fuel cells	1
4.2	Thermodynamics of fuel cells Fuel cell types: AFC	1
4.3	Thermodynamics of fuel cells Fuel cell types: AFC	1
4.4	PEMFC	1
4.5	PEMFC	1
4.6	MCFC	1
4.7	SOFC	1

4.8	Microbial Fuel cell	1
MODULE V		
5.1	Fuel cell usage for domestic power systems	1
5.2	large scale power generation	1
5.3	automobile, space applications	1
5.4	automobile, space applications	1
5.5	economic and environmental analysis on usage of fuel cell	1
5.6	future trends of fuel cells	1

CO Assessment Sample Questions	
1	Explain the properties of hydrogen as a fuel.
2	Explain partial oxidation method of hydrogen production.
3	“Ammonia can serve as a clean hydrogen energy storage medium”. Justify the statement.
4	Explain the working of SOFC.

EIGHTH SEMESTER HONOUR

24CHH809	PROJECT (HONOURS)	L	T	P	J	S	C	Year of Introduction
		0	0	0	4	0	4	2024

Preamble: The objective of Project is to enable the student to take up an investigative study in the broad field of Engineering, either fully theoretical/practical or involving both theoretical and practical work to be assigned by the Department on a group of three/four students, under the guidance of a supervisor.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO1	Identify and synthesize problems and propose solutions to them.
CO2	Prepare a work plan and liaison with the team in completing as per schedule.
CO3	Validate the above solutions by theoretical calculations and through experiments.
CO4	Write technical reports and develop proper communication skills.
CO5	Present the data and defend ideas.

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	-	-	-	-	3	3	-	2
CO2	3	-	-	3	-	-	-	3	-	3	3	-
CO3	3	3	3	3	3	-	-	-	-	3	-	-
CO4	-	-	-	-	3	-	-	3	3	3	-	1
CO5	3	3	3	3	-	-	-	3	-	3	3	1

Assessment Pattern

Bloom's Category	Continuous assessment tools		
	Evaluation 1	Evaluation 2	Evaluation 3
Remember			
Understand	✔	✔	✔
Apply	✔	✔	✔
Analyse	✔	✔	✔
Evaluate			
Create			

Mark Distribution of CIA

Course Structure [L-T-P-J]	Project guide	Interim Evaluation	Draft Report	Final Report	Final Evaluation	Total Marks
0-0-0-4	25	25	5	10	35	100

Total Mark distribution	
Total Marks	CIA (Marks)
100	100

General guidelines

Assessment Pattern

The End Semester Evaluation (ESE) will be conducted as an internal evaluation based on the product, the report and a viva- voce examination, conducted by a 3-member committee appointed by Head of the Department comprising HoD or a senior faculty member, academic coordinator for that program and project guide/coordinator. The Committee will be evaluating the level of completion and demonstration of functionality/specifications, presentation, oral examination, working knowledge and involvement.

The Continuous Internal Evaluation (CIE) is conducted by evaluating the progress of the mini project through a minimum of TWO reviews. At the time of the 1st review, students are supposed to propose a new system/design/idea, after completing a thorough literature study of the existing systms under their chosen area. In the 2nd review students are expected to highlight the implementation details of the proposed solution. The review committee should assess the extent to which the implementation reflects the proposed design. A well coded, assembled and completely functional product is the expected output at this stage. The final CIE mark is the average of 1st and 2nd review marks.

A zeroth review may be conducted before the beginning of the project to give a chance for the students to present their area of interest or problem domain or conduct open brainstorming sessions for innovative ideas. Zeroth review will not be a part of the CIE evaluation process