TKM COLLEGE OF ENGINEERING

(Government Aided and Autonomous)

celebrating 60 years of excellence

Curriculum 2024

M.Tech in Electric Vehicle Technology

(Interdisciplinary)

Academic Year: 2024-25

Preface to the Curriculum

The new postgraduate curriculum of TKM College of Engineering is designed to provide students with the skills and knowledge they need to become competent engineers capable of tackling real-world problems in a variety of fields. The curriculum is carefully designed to expose students to both theoretical and practical aspects of engineering and provide them with hands-on experience in the latest technologies and tools used in the industry. The courses given in the curriculum are tailored in a student centric fashion to ensure that they receive well-rounded education with the flexibility to customize their own learning experience according to their interests and career goals.

The allocation of 68 credits, of which 34 are from theory courses, 2 are from lab courses, 3 are from internship and 29 are from project/research courses, over a period of two years, with each year comprising of two semesters. All courses in the curriculum are designed to highlight the significance of applying knowledge to engineering and technology challenges, fostering creativity and innovation, and developing entrepreneurial /research abilities.

The curriculum includes core courses (both discipline and stream), program elective courses, industry/interdisciplinary elective courses, laboratory courses, course on research methodology & IPR, audit course, MOOC course, mini-project, dissertation/research project in two phases, internship training and teaching assistance ship. These variety of courses ensures that students receive a well-rounded education and have the flexibility to customize their own learning experience according to their interests and career goals.

Students will have the opportunity to choose from a wide range of elective/MOOC/audit courses in specialized areas. The industry internship included in the curriculum will give students the opportunity to apply their theoretical knowledge to practical situations and gain valuable experience. The students can opt for open elective / industry/ interdisciplinary elective courses during 2nd semester and MOOC courses during their 3rd semester, which will give them flexibility in doing internships.

Moreover, the extracurricular activities that students can participate will provide them with a well-versed education and help them develop important skills such as leadership, teamwork, and communication. This is a great initiative by TKM College of Engineering to ensure that students not only excel academically but also develop important life skills that will help them in their future careers.

ASSESSMENT PATTERN

(i) CORE COURSES

Evaluation shall only be based on application, analysis or design-based questions (for both internal and end semester examinations).

Continuous Internal Evaluation: **40 marks**

Micro project/Course based project: (The project shall be done individually. Group projects not permitted.)	20 marks
Course based task/Seminar/Quiz:	10 marks
Test paper, 1 No.: (Test paper shall include minimum 80% of the syllabus.)	10 marks

End Semester Examination: **60 marks**

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks. Total duration of the examination will be 150 minutes.

(ii) ELECTIVE COURSES

Evaluation shall only be based on application, analysis or design-based questions (for both internal and end semester examinations).

Continuous Internal Evaluation: **40 marks**

Preparing a review article based on peer reviewed original publications: (minimum 10 Publications shall be referred)	15 marks
Course based task/Seminar/Data Collection and interpretation:	15 marks
Test paper, 1 No.: (Test paper shall include minimum 80% of the syllabus.)	10 marks

End Semester Examination: **60 marks**

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example, if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

(iii) RESEARCH METHODOLOGY & IPR/AUDIT COURSE

Continuous Internal Evaluation: **40 marks**

Course based task:	15 marks
Seminar/Quiz:	15 marks
Test paper, 1 No.: (Test paper shall include minimum 80% of the syllabus.)	10 marks

End Semester Examination: **60 marks**

The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question can carry 12 marks.

(iv) LABORATORY COURSES

The laboratory courses will be having only Continuous Internal Evaluation and carries 100 marks. Final assessment shall be done by two examiners; one examiner will be a senior faculty from the same department.

(v) INTERDISCIPLINARY ELECTIVE

Engineering students frequently aspire to work in areas and domains that are key topics in the industry. There are concerns by recruiters that skill sets of engineering students did not match with the Industry requirements, especially in the field of latest topics. In response to their desires, the University has incorporated Industry/Interdisciplinary electives in the curriculum. Interdisciplinary knowledge is critical for connecting students with current industry trends, where multitasking is the norm. Interdisciplinary knowledge aids in the bridge- building process between academic institutions and industry. It aids pupils in expanding their knowledge and innovating by allowing them to create something new. While core engineering courses provide students with a strong foundation, evolving technology necessitates new methods and approaches to progress, prosperity, and the inculcation of problem- solving techniques. Other courses' knowledge, on the other hand, can assist them to deal with any scenario more effectively. Interdisciplinary courses may be one approach to address such needs, as they can aid in the enhancement of engineering education and the integration of desirable specialized subjects into the current engineering education system. This will enable students to fulfil the current industry demands. Students with multidisciplinary knowledge and projects are more likely to be placed in top industries, according to the placement trend. The future of developing engineers will be influenced by their understanding of emerging technology and interdisciplinary approaches such as bigdata, machine learning, and 3-D printing.

Continuous Internal Evaluation: **40 marks**

Preparing a review article based on peer reviewed original publications: (minimum 10 Publications shall be referred)	15 marks
Course based task/Seminar/Data Collection and interpretation:	15 marks
Test paper, 1 No.: (Test paper shall include minimum 80% of the syllabus.)	10 marks

End Semester Examination: **60 marks**

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

(vi) MOOC COURSES

The MOOC course shall be considered only if it is conducted by the agencies namely AICTE/NPTEL/SWAYAM or NITTTR. The MOOC course should have a minimum duration of 8 weeks and the content of the syllabus shall be enough for at least 40 hours of teaching. The course should have a proctored/offline end semester examination. The students can do the MOOC according to their convenience, but shall complete it by third semester. The list of MOOC courses will be provided by the concerned BoS if at least 70% of the course content match with the area/stream of study. The course shall not be considered if its content has more than 50% of overlap with a core/elective course in the concerned discipline or with an open elective.

MOOC Course to be successfully completed before the commencement of fourth semester (starting from semester 1). A credit of 2 will be awarded to all students whoever successfully completes the MOOC course as per the evaluation pattern of the respective agency conducting the MOOC.

(vii) MINIPROJECT

Total marks: **100**, only CIA

Mini project can help to strengthen the understanding of student's fundamentals through application of theoretical concepts and to boost their skills and widen the horizon of their thinking. The ultimate aim of an engineering student is to resolve a problem by applying theoretical knowledge. Doing more projects increases problem- solving skills. The introduction of mini projects ensures preparedness of students to undertake dissertation. Students should identify a topic of interest in consultation with PG Programme Coordinator that should lead to their dissertation/research project. Demonstrate the novelty of the project through the results and outputs. The progress of the mini project is evaluated based on three reviews, two interim reviews and a final review. A report is required at the end of the semester.

Interim evaluation (20 marks for each review):	40 marks
Final evaluation by a Committee (will be evaluating the level of completion and demonstration of functionality/specifications, clarity of presentation, oral examination, work knowledge and involvement):	35 marks
Report (the committee will be evaluating for the technical content, adequacy of references, templates followed and permitted plagiarism level is not more than 25%):	15 marks
Evaluation by Supervisor/Guide:	10 marks

TEACHING ASSISTANCESHIP (TA)

All M.Tech students irrespective of their category of admission shall undertake TA duties for a minimum duration as per the curriculum. Being a TA, the student will get an excellent opportunity to improve their expertise in the technical content of the course, enhance communication skills, obtain a hands-on experience in handling the experiments in the laboratory and improve peer interactions.

The possible TA responsibilities include the following: facilitate a discussion section or tutorial for a theory/ course, facilitate to assist the students for a laboratory course, serve as a mentor for students, and act as the course web-master. TAs may be required to attend the instructor's lecture regularly. A TA shall not be employed as a substitute instructor, where the effect is to relieve the instructor of his or her teaching responsibilities (specifically prohibited by University Policy).

For the tutorial session:

(i) Meet the teacher and understand your responsibilities well in advance, attend the lectures of the course for which you are a tutor, work out the solutions for all the tutorial problems yourself, approach the teacher if you find any discrepancy or if you need help in solving the tutorial problems, use reference text books, be innovative and express everything in English only.

(ii) Try to lead the students to the correct solutions by providing appropriate hints rather than solving the entire problem yourself, encourage questions from the students, lead the group to a discussion based on their questions, plan to ask them some questions be friendly and open with the students, simultaneously being firm with them.

(iii) Keep track of the progress of each student in your group, give a periodic feedback to the student about his/her progress, issue warnings if the student is consistently under-performing, report to the faculty if you find that a particular student is consistently underperforming, pay special attention to slow-learners and be open to the feedback and comments from the students and faculty.

(iv) After the tutorial session you may be required to grade the tutorials/assignments/tests. Make sure that you work out the solutions to the questions yourself, and compare it with the answer key, think and work out possible alternate solutions to the same question, understand the marking scheme from the teacher. Consult the teacher if are and make sure that you are not partial to some student/students while grading. Follow basic ethics.

Handling a laboratory Session:

(i) Meet the faculty – in- charge a few days in advance of the actual lab class and get the details of the experiment, get clarifications from him/her regarding all aspects of the experiment and the expectations, prepare by reading about the theoretical background of the experiment, know the physical concepts involved in the experiment, go to the laboratory and check out the condition of the equipment/instrumentation, perform the laboratory experiment at least once one or two days before the actual laboratory class, familiarize with safety/ security aspects of the experiment / equipment/laboratory, prepare an instruction sheet for the experiment in consultation with the faculty, and keep sufficient copies ready for distribution to students for their reference.

(ii) Verify condition of the equipment/set up about 30 minutes before the students arrive in the class and be ready with the hand outs, make brief introductory remarks about the experiment, its importance, its relevance to the theory they have studied in the class, ask the students suitable questions to know there level of preparation for the experiment, discuss how to interpret results, ask them comment on the results.

(iii) Correct/evaluate/grade the submitted reports after receiving suitable instructions from the faculty in charge, continue to interact with students if they have any clarifications regarding any aspect of the laboratory session, including of course grading, Carefully observe instrument and human safety in laboratory class, Preparing simple questions for short oral quizzing during explanation of experiments enables active participation of students, facilitate attention, provides feedback and formative assessment.

CURRICULUM

MTECH 2024

Discipline: ELECTRICAL & ELECTRONICS ENGG.
Stream: ELECTRIC VEHICLE TECHNOLOGY

SEMESTER I							
SLOT	**COURSE CODE**	**COURSE NAME**	**MARKS**		**L-T-P**	**Hrs.**	**CREDIT**
			CIA	**ESE**			
A	221TEE015	E-MOBILITY	40	60	3-0-0	3	3
B	221TEE016	MECHANICAL SYSTEMS OF ELECTRICAL VEHICLES	40	60	3-0-0	3	3
C	221TEE017	POWER CONVERTERS AND MOTOR DRIVES	40	60	3-0-0	3	3
D	221EXXXXX	PROGRAM ELECTIVE 1	40	60	3-0-0	3	3
E	221EXXXXX	PROGRAM ELECTIVE 2	40	60	3-0-0	3	3
S	221RGE100	RESEARCH METHODOLOGY AND IPR	40	60	2-0-0	2	2
T	221LEE006	EV MODELING AND SIMULATION LAB	100	--	0-0-2	2	1
		Total	**340**	**360**		**19**	**18**

Teaching Assistance: 6 hours

PROGRAM ELECTIVE 1						
SLOT	**SL NO**	**COURSE CODE**	**COURSE NAME**	**L-T-P**	**Hrs.**	**CREDIT**
D	1	221EEE009	ENERGY STORAGE CONCEPTS AND APPLICATIONS	3-0-0	3	3
	2	221EEE010	RENEWABLE ENERGY CONVERSION SYSTEMS	3-0-0	3	3
	3	221EEE011	SENSORS AND INSTRUMENTATION	3-0-0	3	3

PROGRAM ELECTIVE 2						
SLOT	**SL NO**	**COURSE CODE**	**COURSE NAME**	**L-T-P**	**Hrs.**	**CREDIT**
E	1	221EEE026	ANALYSIS OF AUTOMOTIVE STRUCTURES	3-0-0	3	3
	2	221EEE033	THERMAL MANAGEMENT OF ELECTRIC VEHICLES	3-0-0	3	3
	3	221EEE034	SIMULATION AND ANALYSIS OF FLUID FLOW AND HEAT TRANSFER PHENOMENA	3-0-0	3	3

SEMESTER II							
SLOT	COURSE CODE	COURSE NAME	MARKS		L-T-P	Hrs.	CREDIT
			CIA	ESE			
A	222TEE008	BATTERY MANAGEMENT SYSTEMS FOR EVs	40	60	3-0-0	3	3
B	222TEE009	VEHICLE DYNAMICS AND CONTROL	40	60	3-0-0	3	3
C	222EXXXXX	PROGRAM ELECTIVE 3	40	60	3-0-0	3	3
D	222EXXXXX	PROGRAM ELECTIVE 4	40	60	3-0-0	3	3
E	222EEXXXX/ 222EEEXXX	INDUSTRY/ INTERDISCIPLINARY ELECTIVE	40	60	3-0-0	3	3
S	222PEE100	MINI PROJECT	100	--	0-0-4	4	2
T	222LEE006	EV HARDWARE LAB	100	--	0-0-2	2	1
		Total	**400**	**300**		**21**	**18**

Teaching Assistance: 6 hours

PROGRAM ELECTIVE 3						
SLOT	SL NO	COURSE CODE	COURSE NAME	L-T-P	Hrs.	CREDIT
C	1	222EEE037	SPECIAL ELECTRICAL MACHINES AND DRIVES	3-0-0	3	3
	2	222EEE046	ELECTRIC VEHICLE ENGINEERING AND DEVELOPMENT	3-0-0	3	3
	3	222EEE012	EMBEDDED PROCESSORS AND CONTROLLERS	3-0-0	3	3

PROGRAM ELECTIVE 4						
SLOT	SL NO	COURSE CODE	COURSE NAME	L-T-P	Hrs.	CREDIT
D	1	222EEE008	DESIGN OF POWER ELECTRONIC SYSTEM	3-0-0	3	3
	2	222EEE020	HYDROGEN AND FUEL CELL TECHNOLOGIES	3-0-0	3	3
	3	222EEE022	EV CHARGING SYSTEMS	3-0-0	3	3

INTERDISCIPLINARY/ INDUSTRY ELECTIVE						
SLOT	SL NO	COURSE CODE	COURSE NAME	L-T-P	Hrs.	CREDIT
E	1	222EEE056	ELECTRIC AND HYBRID VEHICLES	3-0-0	3	3
	2	222EEE071	ELECTRIC CHARGING SYSTEMS FOR ELECTRICAL VEHICLES	3-0-0	3	3

SEMESTER III							
SLOT	COURSE CODE	COURSE NAME	MARKS		L-T-P	Hrs.	CREDIT
			CIA	ESE			
TRACK 1							
A*	223MEEXXX	MOOC	To be completed successfully		--	--	2
B	223AGEXXX	AUDIT COURSE	40	60	3-0-0	3	--
C	223IEE100	INTERNSHIP	50	50	--	--	3
D	223PEE100	DISSERTATION PHASE 1	100	--	0-0-17	17	11
TRACK 2							
A*	223MEEXXX	MOOC	To be completed successfully		--	--	2
B	223AGEXXX	AUDIT COURSE	40	60	3-0-0	3	--
C	223IEE100	INTERNSHIP	50	50	---	--	3
D	223PEE001	RESEARCH PROJECT PHASE 1	100	--	0-0-17	17	11
		Total	**190**	**110**		**20**	**16**

Teaching Assistance: 6 hours

*MOOC Course to be successfully completed before the commencement of fourth semester (starting from semester 1).

AUDIT COURSE						
SLOT	SL NO	COURSE CODE	COURSE NAME	L-T-P	Hrs.	CREDIT
B	1	223AGE100	ACADEMIC WRITING	3-0-0	3	-
	2	223AGE001	ADVANCED ENGINEERING MATERIALS	3-0-0	3	-
	3	223AGE002	FORENSIC ENGINEERING	3-0-0	3	-
	4	223AGE003	DATA SCIENCE FOR ENGINEERS	3-0-0	3	-
	5	223AGE004	DESIGN THINKING	3-0-0	3	-
	6	223AGE005	FUNCTIONAL PROGRAMMING IN HASKELL	3-0-0	3	-
	7	223AGE009	PRINCIPLES OF AUTOMATION	3-0-0	3	-
	8	223AGE010	REUSE AND RECYCLE TECHNOLOGY	3-0-0	3	-
	9	223AGE011	SYSTEM MODELING	3-0-0	3	-
	10	223AGE012	EXPERT SYSTEMS	3-0-0	3	-

SEMESTER IV							
SLOT	**COURSE CODE**	**COURSE NAME**	**MARKS**		**L-T-P**	**Hrs.**	**CREDIT**
			CIA	**ESE**			
TRACK 1							
A	224PEE100	DISSERTATION PHASE II	100	100	0-0-24	24	16
TRACK 2							
A	224PEE001	RESEARCH PROJECT PHASE II	100	100	0-0-24	24	16
		Total	**100**	**100**		**24**	**16**

Teaching Assistance: 5 hours

SYLLABUS

MTECH 2024

Discipline: ELECTRICAL & ELECTRONICS ENGG.

Stream: ELECTRIC VEHICLE TECHNOLOGY

SEMESTER I

SLOT	COURSE CODE	COURSE NAME	MARKS		L-T-P	Hrs.	CREDIT
			CIA	ESE			
A	221TEE015	E-MOBILITY	40	60	3-0-0	3	3
B	221TEE016	MECHANICAL SYSTEMS OF ELECTRICAL VEHICLES	40	60	3-0-0	3	3
C	221TEE017	POWER CONVERTERS AND MOTOR DRIVES	40	60	3-0-0	3	3
D	221EXXXXX	PROGRAM ELECTIVE 1	40	60	3-0-0	3	3
E	221EXXXXX	PROGRAM ELECTIVE 2	40	60	3-0-0	3	3
S	221RGE100	RESEARCH METHODOLOGY AND IPR	40	60	2-0-0	2	2
T	221LEE006	EV MODELING AND SIMULATION LAB	100	--	0-0-2	2	1
		Total	**340**	**360**		**19**	**18**

PROGRAM ELECTIVE 1						
SLOT	**SL NO**	**COURSE CODE**	**COURSE NAME**	**L-T-P**	**Hrs.**	**CREDIT**
D	1	221EEE009	ENERGY STORAGE CONCEPTS AND APPLICATIONS	3-0-0	3	3
	2	221EEE010	RENEWABLE ENERGY CONVERSION SYSTEMS	3-0-0	3	3
	3	221EEE011	SENSORS AND INSTRUMENTATION	3-0-0	3	3

PROGRAM ELECTIVE 2						
SLOT	**SL NO**	**COURSE CODE**	**COURSE NAME**	**L-T-P**	**Hrs.**	**CREDIT**
E	1	221EEE026	ANALYSIS OF AUTOMOTIVE STRUCTURES	3-0-0	3	3
	2	221EEE033	THERMAL MANAGEMENT OF ELECTRIC VEHICLES	3-0-0	3	3
	3	221EEE034	SIMULATION AND ANALYSIS OF FLUID FLOW AND HEAT TRANSFER PHENOMENA	3-0-0	3	3

221TEE015	E-MOBILITY	Category	L-T-P-C	YOI
		Program Core 1	3-0-0-3	2022

Preamble: Electric vehicles have emerged as a promising area to reduce emission in the transportation sector. Drastic development in electric vehicles also created multi-faceted technological challenges. This course provides a comprehensive coverage on various drive train topologies, energy storage technologies and control strategies of Electric and Hybrid Vehicles.

Course Prerequisites: Nil

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

CO 1	Explain various characteristics of conventional vehicles and compare them with hybrid & electric vehicles
CO 2	Analyze the various drive train topologies for hybrid & electric vehicles
CO 3	Distinguish the various energy storage systems
CO 4	Analyze the various energy management strategies
CO 5	Examine impact of electric vehicles on power system

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	1		3	2	
CO 2	3	2			3	2	
CO 3	3	2	1		3	2	
CO 4	3	2			3	2	
CO 5	3	2			3	2	

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Understand	60%	**100**	**40**	**60**	**2.5** hours
Apply	20%				
Analyse	20%				
Evaluate	--				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Micro project/Course based project (The project shall be done individually. Group projects not permitted.) :20 marks
Course based task/Seminar/Quiz :10 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.) :10 marks

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions, with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions, with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks.

SYLLABUS

MODULE I: Introduction to Hybrid & Electric Vehicles (9 Hrs.)

Introduction to Hybrid & Electric Vehicles: Review of Conventional Vehicle, basics of vehicle performance, vehicle power source characterization, Transmission characteristics, mathematical models to describe vehicle performance, Tractive effort in normal driving, Drive cycles and their impact on vehicle operation.

Basic principles and trends of smart mobility, concept of e-mobility, Types of EVs, Power flow control in EVs
MODULE II: Hybrid Electric Drive-trains (8 Hrs.)
Hybrid Electric Drive-trains: Concept of Hybrid Electric Drive Trains, Architecture of Hybrid Electric Drive Trains, Series Hybrid Electric Drive Trains, Parallel hybrid electric drive trains, Series -parallel hybrid, Electric Propulsion unit Configuration and control of Electric motor drives-BLDC drives, Induction Motor drives, PMSM drives, switched reluctance motor.
MODULE III: Energy storage System (8 Hrs.)
Energy storage System: Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Hybridization of different energy storage devices, Sizing the drive system Design of Hybrid Electric Vehicle and Plug-in Electric Vehicle.
MODULE IV: Energy Management System (8 Hrs.)
Energy Management System: Energy Management Strategies, Automotive networking and communication, EV charging standards, V2G, G2V, V2B, V2H, Business: E-mobility business, electrification challenges, Connected Mobility and Autonomous Mobility- case study E-mobility Indian Roadmap Perspective, Policy: EVs in infrastructure system, integration of EVs in smart grid, social dimensions of EVs.
MODULE V: Influence of EVs on power system (7 Hrs.)
Influence of EVs on power system: Introduction, identification of EV demand, EV penetration level for different scenarios, classification based on penetration level, EV impacts on system demand: dumb charging, multiple tariff charging, smart charging, case studies.
Text book: 1. Iqubal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press 2. Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Modern Electric, Hybrid and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press
References: 1. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley 2. R. Krishnan, Permanent Magnet Synchronous and Brushless DC Motors Drives, CRC Press 3. John G. Hayes, Abas Goodarzi, Electric Powertrain Energy Systems, Power Electronics and Drives for Hybrid, Electric and Fuel Cell Vehicles, Wiley

COURSE PLAN		
No.	**Topic**	**No. of Lectures**
1	**MODULE I (9 hours)**	
1.1	Introduction to Hybrid & Electric Vehicles: Review of Conventional Vehicle, basics of vehicle performance, vehicle power source characterization, Transmission characteristics	3
1.2	Mathematical models to describe vehicle performance, Tractive effort in normal driving, Drive cycles and their impact on vehicle operation.	3
1.3	Basic principles and trends of smart mobility, concept of e-mobility	1
1.4	Types of EVs, Power flow control in EVs	2
2	**MODULE II (8 hours)**	
2.1	Hybrid Electric Drive-trains: Concept of Hybrid Electric Drive Trains, Architecture of Hybrid Electric Drive Trains, Series Hybrid Electric Drive Trains, Parallel hybrid electric drive trains,	3
2.2	Electric Propulsion unit, Configuration and control of Electric motor drives-BLDC drives, Induction Motor drives, PMSM drives,	5

	switched reluctance motor.	
3	**MODULE III (8 hours)**	
3.1	Energy storage System: Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery based energy storage and its analysis	3
3.2	Fuel Cell based energy storage and its analysis	1
3.3	Hybridization of different energy storage devices	1
3.4	Sizing the drive system,	1
3.5	Design of Hybrid Electric Vehicle and Plug-in Electric Vehicle	2
4	**MODULE IV (8 hours)**	
4.1	Energy Management System: Energy Management Strategies, Automotive networking and communication	3
4.2	EV charging standards, V2G, G2V, V2B, V2H	1
4.3	Business: E-mobility business, electrification challenges, Connected Mobility and Autonomous Mobility, case study E-mobility Indian Roadmap Perspective	2
4.4	Policy: EVs in infrastructure system, integration of EVs in smart grid, social dimensions of EVs.	2
5	**MODULE V (7 hours)**	
5.1	Influence of EVs on power system: Introduction, identification of EV demand, EV penetration level for different scenarios, classification based on penetration level,	4
5.2	EV impacts on system demand: dumb charging, multiple tariff charging, smart charging, case studies.	3

MODEL QUESTION PAPER		
FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR		
221TEE015 E-MOBILITY		
Max. Marks: 60		**Time: 2.5 Hrs.**
Sl.	**Part A (Answer all questions)**	**Marks**
1	Explain different drive cycles applied to EVs.	(5)
2	Discuss the architecture of parallel hybrid electric drive train.	(5)
3	What is meant by hybridization of energy storage devices?	(5)
4	Distinguish between connected mobility and e-mobility	(5)
5	Discuss multiple tariff charging	(5)
	Part B (Answer any five questions)	
6	Develop mathematical model to describe the performance of conventional vehicles	(7)
7	Discuss the different speed control methods for IM drives.	(7)
8	Explain the detailed design procedure of a Hybrid electric vehicle.	(7)
9	With neat diagrams explain the architectural classification of Hybrid electric vehicles.	(7)
10	Discuss the Policies governing the integration of EVs in infrastructure system	(7)
11	Discuss the Influence of EVs on power system.	(7)
12	Explain the technologies involved in fuel cell-based energy storage system.	(7)

221TEE016	MECHANICAL SYSTEMS OF ELECTRICAL VEHICLES	Category	L-T-P-C	YOI
		Discipline Core 1	3-0-0-3	2022

Preamble: Nil

Course Prerequisites: Nil

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

CO 1	Do the sizing of an EV drive train
CO 2	Select the gears and bearings for the transmission system
CO 3	Device braking system
CO 4	Sizing of HVAC system
CO 5	Size cooling system for power electronic devices

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3		2	3		2	
CO 2	3		2	3		2	
CO 3	3		3	3		3	
CO 4	3		3	3		3	
CO 5	3		3	3		3	

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Apply	70%	100	40	60	2.5 hours
Analyse	20%				
Evaluate	10%				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Micro project/Course based project (The project shall be done individually. Group projects not permitted.) :20 marks

Course based task/Seminar/Quiz :10 marks

Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.) :10 marks

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions, with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions, with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks. Total duration of the examination will be 150 minutes.

SYLLABUS

MODULE I

Sizing of EV drive train: Load calculation, Performance calculations, top speed, gradability, acceleration, torque, range, motor specification and gearbox specification. Simulation model of EV drivetrain

MODULE II

Transmission system: Types of gears, Gear trains, Single and multi-ratio gearbox systems, CV shafts, drive shafts, bearing selection, duty cycle, NVH optimization, Lead and profile modification to achieve NVH, Efficiency, and durability targets, bearing selection, Bearing life calculation

MODULE III

Braking system: Determination of braking distance, Types of brakes-, regenerative braking system, Combined braking system calculation, anti-lock braking system.
MODULE IV
Heating, ventilation, and Air conditioning system (HVAC) system: Heating and cooling system, cooling load calculation, Dual-operation HVAC systems
MODULE V
Calculation of thermal load from equipment, Battery pack cooling methods, Motor cooling, Power electronics cooling- MCU/Charger/ DC-DC converters.
Text book: 1. Electric Vehicle Technology Explained" by James Larminie and John Lowry 2. Electric and Hybrid Vehicles: Design Fundamentals" by Iqbal Husain
References: 1. Electric Vehicle Technology and Design" by Alan Vesprini 2. Electric Drives and Electromechanical Systems: Applications and Control" by Sergey Edward Lyshevski

COURSE PLAN		
No.	**Topic**	**No. of Lectures**
1	**MODULE I (8 hours)**	
1.1	Sizing of EV drive train: Load calculation, Performance calculations,	2
1.2	Top speed, gradability, acceleration, torque, range,	2
1.3	Motor specification and gearbox specification.	2
1.4	Simulation model of EV drivetrain	2
2	**MODULE II (8 hours)**	
2.1	Transmission system: Types of gears, Gear trains, Single and multi-ratio gearbox systems,	2
2.2	CV shafts, drive shafts, bearing selection, duty cycle,	2
2.3	NVH optimization, Lead and profile modification to achieve NVH, Efficiency, and durability targets,	2
2.4	Bearing selection, Bearing life calculation	2
3	**MODULE III (8 hours)**	
3.1	Braking system: Determination of braking distance,	2
3.2	Types of brakes-, regenerative braking system,	2
3.3	Combined braking system calculation,	2
3.4	Anti-lock braking system.	2
4	**MODULE IV (8 hours)**	
4.1	Heating, ventilation, and Air conditioning system (HVAC) system: Heating and cooling system,	3
4.2	cooling load calculation.,	3
4.3	Dual-operation HVAC systems	2
5	**MODULE V (8 hours)**	
5.1	Calculation of thermal load from equipment,	2
5.2	Battery pack cooling methods,	2
5.3	Motor cooling, Power electronics cooling- MCU/	2
5.4	Charger/ DC-DC converters.	2

MODEL QUESTION PAPER		
FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR		
221TEE016 MECHANICAL SYSTEMS OF ELECTRICAL VEHICLES		
Max. Marks: 60		Time: 2.5 Hrs.
Sl.	**Part A** **(Answer all questions)**	**Marks**
1	What factors determine the range of an electric vehicle?	(5)
2	Describe the process of calculating bearing life in a transmission system	(5)
3	How is braking distance determined for a vehicle?	(5)
4	How is the cooling load for an HVAC system calculated in a vehicle?	(5)
5	What are the key challenges in cooling power electronics in high-performance electric vehicles?	(5)
	Part B **(Answer any five questions)**	
6	Calculate the time it takes for an electric vehicle to accelerate from 0 to 60 km/h, given a motor power of 80 kW and a total vehicle mass of 1,400 kg. Assume that 90% of the motor's power is used for acceleration, and ignore air resistance for simplicity.	(7)
7	The parameters of a parallel HEV are as follows: Vehicle mass-1800kg, driver/passenger-80kg, rolling resistance coefficient-0.01, aerodynamic drag coefficient -0.4, frontal area-2.6m^2. The vehicle is to accelerate uniformly from 0 to 60mphr in 10 seconds. Find an expression for traction power as a function of time.	(7)
8	Design a two-stage helical gearbox to transmit 200 kW of power from an electric motor running at 3000 RPM to a drive axle operating at 300 RPM. (The selection of gear ratio, number of stages, determination of module and centre to centre distance is enough)	(7)
9	A 2,000 kg vehicle traveling at 85 mph has to be stopped with a maximum sustained deceleration of 0.65 g. The vehicle has a wheelbase of 2.5 m and a front/rear static weight distribution of 49%/51%. The centre of gravity is at a height of 0.5 m from the ground. a. Find the total force and average power required to bring the vehicle to a stop. b. Find the average power absorbed by the brakes. c. Find the front and rear weight distribution during braking.	(7)
10	How does anti-lock brake system work?	(7)
11	How do dual-operation systems manage both heating and cooling simultaneously?	(7)
12	What are the key cooling techniques used for managing the thermal load in power electronics, such as MCUs, chargers, and DC-DC converters?	(7)

221TEE017	POWER CONVERTERS AND MOTOR DRIVES	Category	L-T-P-C	YOI
		Program Core 2	3-0-0-3	2022

Preamble: This course intends to provide in-depth knowledge on different power semiconductor devices and detailed analysis of various power conversion techniques.

Course Prerequisites: Nil

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

CO 1	Acquire knowledge about various types of electric power trains configurations and power semiconductor devices
CO 2	Analyse various single-phase and three-phase controlled rectifier circuits to operate in various quadrants
CO 3	Design different types of DC-DC converters and evaluate its control techniques
CO 4	Analyse AC-DC converters and its control techniques
CO 5	Analyse various types of motor drives and its control for EVs

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	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	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Apply	60%	100	40	60	2.5 hours
Analyse	20%				
Evaluate	20%				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Micro project/Course based project
(The project shall be done individually. Group projects not permitted.) :20 marks
Course based task/Seminar/Quiz :10 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.) :10 marks

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions, with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions, with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks.

SYLLABUS

MODULE I (6 Hours)

Review of conventional vehicle powertrain. Electric Powertrain – Hybrid (series, parallel, series-parallel, complex), Plug-in Hybrid, Battery EV and Fuel cell EV architectures- block diagram of EV propulsion systems. Single motor, multi-motor and in-wheel configurations. Distribution of electric power in EV and role of AC-DC, DC-DC, DC-AC power converters.

Review of power semiconductor switches – characteristics of ideal and practical switches. Power Diode, SCR, power MOSFET, IGBT - static and dynamic characteristics. Gate drive requirements.

MODULE II (8 Hours)

AC-DC Converters – Single phase and three phase diode rectifiers. Single-phase fully-controlled and semi-controlled bridge rectifiers - analysis with R and RL loads only.
Three-phase fully-controlled and semi-controlled bridge rectifiers circuits; inversion mode. PWM rectifiers for bidirectional power flow.
*Simulation of AC-DC converters using MATLAB/ SIMULINK (Assignment/ Project) **

MODULE III (8 Hours)

DC-DC converters – Buck, boost, buck-boost converters– continuous conduction only – design of L and C. Performance analysis. Bidirectional DC-DC converters.
DC-AC Converters – Single Phase and Three Phase Inverters. Single phase and Three phase PWM Techniques- Space Vector PWM, Hysteresis Control, Comparison of PWM techniques.
*Simulation of DC-DC and/ or DC-AC converters using MATLAB/ SIMULINK (Assignment/ Project) **

MODULE IV (7 Hours)

Induction Motor for EV powertrain, Variable Voltage Variable Frequency Control - Steady State Analysis of Induction Drive, Direct & Indirect Vector Control, and Direct Torque Control.
BLDC drives-various speed control strategies – closed loop control – Control strategies of regenerative braking in drives.
*Simulation of speed control of induction motor and/ or BLDC motor using MATLAB/ SIMULINK (Assignment/ Project) **

MODULE V (9 Hours)

Permanent magnet synchronous machine for EV powertrain, Non-Salient & Salient Drives, Generic Model, Steady State Analysis, Field Oriented Control.
Switched Reluctance Machine for EV powertrain. Operating principles, Analysis of SRM drives and speed control.
Transmission and Drivetrain Characteristics, Regenerative Braking Characteristics. Tractive effort in normal driving, Energy consumption concept. Different types of motors used and its comparative study.
*Simulation of speed control of PMSM and/ or SRM motor using MATLAB/ SIMULINK (Assignment/ Project) **
**The Assignment/ Project can also be completed as a part of 221LEE006 EV Modeling and Simulation Lab*

Text book:

1. Ned Mohan, Tore Undeland and Willima Robbins, "Power Electronics - Converters, Applications and Design", John Wiley & Sons, Inc.
2. Muhammad H. Rashid, "Power Electronics – Circuits, Devices and Applications", Pearson, 3rd edition
3. Bimal K Bose; Modern Power Electronics and AC Drives, Pearson Education, second Edition, 2003
4. R Krishnan, Electric motor drives: Modelling, Analysis, and Control, 2013.

References:

1. Ali Emadi, "Handbook of Automotive Power Electronics and Drives", Taylor & Francis Group, First Edition, USA, 2005.
2. C C Chan and K T Chau, "Modern Electric Vehicle Technology", Oxford University Press, 2001.
3. Iqbal Hussain, "Electric and Hybrid Vehicles – Design fundamentals", CRC Press, 2021.
4. Ali Emadi, "Advance Electric Drive Vehicles", CRC Press, 2015.
5. David Crolla, Behrooz Mashadi, "Vehicle Powertrain Systems", Wiley.

COURSE PLAN		
No.	**Topic**	**No. of Lectures**
1	**MODULE I (6 hours)**	
1.1	Review of conventional vehicle powertrain. Electric Powertrain- Hybrid (series, parallel, series-parallel, complex), Plug-in Hybrid, Battery EV and Fuel cell EV architectures- block diagram of EV propulsion systems. Single motor, multi-motor and in-wheel configurations.	2
1.2	Distribution of electric power in EV and role of AC-DC, DC- DC, DC-AC power converters.	1
1.3	Review of power semiconductor switches – characteristics of ideal and practical switches. Power Diode, SCR, power MOSFET, IGBT - static and dynamic characteristics. Gate drive requirements.	3
2	**MODULE II (8 hours)**	
2.1	AC-DC Converters – Single phase and three phase diode rectifiers.	2
2.2	Single-phase fully-controlled and semi-controlled bridge rectifiers - analysis with R and RL loads only.	3
2.3	Three-phase fully-controlled and semi-controlled bridge rectifiers circuits; inversion mode (Basics no need of derivations).	2
2.4	PWM rectifiers for bidirectional power flow.	1
3	**MODULE III (8 hours)**	
3.1	DC-DC converters – Buck, boost, buck-boost converters– continuous conduction only – design of L and C.	3
3.2	Bidirectional DC-DC converters.	1
3.3	DC-AC Converters – Single Phase and Three Phase Inverters.	2
3.4	Single phase and Three phase PWM Techniques- Space Vector PWM, Hysteresis Control, Comparison of PWM techniques.	2
4	**MODULE IV (7 hours)**	
4.1	Induction Motor for EV powertrain, Variable Voltage Variable Frequency Control - Steady State Analysis of Induction Drive.	2
4.2	Direct & Indirect Vector Control, and Direct Torque Control (Basics and block diagram).	2
4.3	BLDC drives-various speed control strategies – closed loop control – Control strategies of regenerative braking in drives	3
5	**MODULE V (9 hours)**	
5.1	Permanent magnet synchronous machine for EV powertrain, Non-Salient & Salient Drives, Generic Model, Steady State Analysis, Field Oriented Control (Basics and block diagram).	3
5.2	Switched Reluctance Machine for EV powertrain. Operating principles, Analysis of SRM drives and speed control (Basics and block diagram).	3
5.3	Transmission and Drivetrain Characteristics, Regenerative Braking Characteristics. Tractive effort in normal driving, Energy consumption concept. Different types of motors used and its comparative study.	3

MODEL QUESTION PAPER		
FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR		
221TEE017 POWER CONVERTERS AND MOTOR DRIVES		
Max. Marks: 60		Time: 2.5 Hrs.
Sl.	**Part A (Answer all questions)**	**Marks**
1	List the ideal and practical characteristics of power semiconductor switches.	(5)
2	Derive the expression for distortion factor of 1-phase full converter with RL load in continuous current mode (io=Io).	(5)
3	Derive the input-output voltage relation of a buck-boost converter.	(5)
4	With a block diagram, describe the principle of direct torque control of induction motor.	(5)
5	Derive the model of PMSM motor and find the state-space matrices.	(5)
	Part B (Answer any five questions)	
6	Describe various hybrid electrical powertrain configurations with block diagrams.	(7)
7	For a 3-phase full converter operating from 3-phase, 415V, 50Hz supply and driving a large inductive load (load current is continuous and ripple free) with R = 100Ω, draw the load voltage and source current (in any one line) waveforms for a firing angle of 30°. Also find the displacement power factor, distortion factor, harmonic factor and input power factor.	(7)
8	A buck-boost converter is operated from a 24V battery and supplies an average load current of 2A. Its switching frequency is 50KHz. Neglecting diode and switch drop, determine i) Range of duty cycle variation required to maintain the output voltage at 15V, given that the battery voltage ranges from 26V in the fully charged state to 21V in the discharged state. ii)The peak to peak choke ripple current for the nominal supply voltage, given that the choke value is 500µH. Average supply current drawn from the battery under normal condition.	(7)
9	A three-phase bridge inverter is supplied from a 600V source. For a star connected resistive load of 15Ω/phase, find the RMS load current, the load power and the thyristor ratings for 180° conduction. Also, draw the output line voltage and line current (in any one line only) waveforms	(7)
10	Draw and explain the block schematics of indirect vector control scheme of induction motor drive.	(7)
11	Explain the controls strategies of BLDM Motor drive with necessary equations.	(7)
12	Explain the construction and operation principle of SRM motor.	(7)

221EEE009	ENERGY STORAGE CONCEPTS AND APPLICATIONS	Category	L-T-P-C	YOI
		Program Elective 1	3-0-0-3	2022

Preamble: This course provides an introduction to energy storage technologies and equips the students to select suitable energy storage systems for various industrial applications.

Course Prerequisites: Nil

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

CO 1	Illustrate different types of energy storage systems.
CO 2	Select battery packs to suit customer requirements
CO 3	Apply the theory of ultracapacitors for energy storage
CO 4	Compare different fuel cell technologies for energy storage.
CO 5	Design of battery packs for Electric Vehicles in various applications.

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	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	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Apply	40%	100	40	60	2.5 hours
Analyse	40%				
Evaluate	20%				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred) :15 marks

Course based task/Seminar/Data collection and interpretation :15 marks

Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.) :10 marks

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions, with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions, with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks.

SYLLABUS

MODULE I (6 hours)

Need of energy storage - different types of energy storage; Potential energy - pumped hydro storage; Compressed gas system- compressed air energy storage; Kinetic energy - Flywheel storage operation - principles of flywheels - power capacity of flywheel systems -flywheel technologies; Fossil fuels and synthetic fuels; Solar ponds for energy storage; Electrical and magnetic energy storage - capacitors - electromagnets; Chemical energy storage - Thermo-chemical, photo-chemical, bio-chemical, electro- chemical systems; Comparison of energy storage technologies; Hybridization of energy storages.

Fundamental concepts of batteries - Primary and secondary batteries - electrochemical reactions - thermodynamic voltage - battery equivalent circuit.

MODULE II (11 hours)

Battery parameters - storage density - energy density - energy efficiency - charge efficiency, specific energy - specific power - state of charge (SoC) - state of health (SoH) - state of function (SoF); Measurement of battery performance; Factors affecting battery cell life cycles - C rate - depth of discharge (DoD).

Battery Technologies - Lead-acid batteries - Nickel-based batteries: Nickel/iron, nickel/cadmium, nickel–metal hydride (Ni–MH) - applications - Lithium-based batteries: Lithium–polymer (Li–P), Lithium-ion (Li-Ion), Lithium-Cobalt, Lithium Manganese Oxide, Lithium Iron Phosphate (LiFP), Lithium Nickel Manganese Cobalt Oxide (NMC), Lithium Nickel Cobalt Aluminium Oxide (NCA), Lithium Titanate – Applications.

Battery pack development process - Electrical design of battery pack - busbar design; Battery cell testing - testing standards -safety issues; Charging and discharging of a battery - Charge / Discharge characteristics.

MODULE III (7 hours)

Magnetic and Electric Energy Storage Systems:

Superconducting magnetic energy storage (SMES) systems; Capacitors; Ultra-capacitor - Basic principles - equivalent circuit. Ultra-capacitor technologies: Electrochemical double layer capacitor (EDLC) - principle of working - structure - performance and applications; Role of activated carbon and carbon nano-tubes in performance enhancement; Comparison of Ultra-capacitor characteristics with batteries - applications.

MODULE IV (10 hours)

Fuel Cells: Operating principle of fuel cells: Electrode potential and current–voltage curve

Fuel cell reactions with alkaline / acid / molten carbonate / ceramic electrolytes / Methanol fuel cells; Fuel cell system characteristics; Circuit model

Hydrogen as energy carrier - Hydrogen storage - Hydrogen production: Compressed hydrogen, cryogenic liquid hydrogen, metal hydrides.

Fuel cell technologies: Alkaline fuel cells (AFC), Phosphoric acid fuel cells (PAFC)

Molten carbonate fuel cells (MCFC), Solid oxide fuel cells (SOFC), Non-hydrogen fuel cells, Direct methanol fuel cells (DMFC), Proton exchange membrane (PEM) fuel cells, Rechargeable fuel cells, Applications.

Hybrid fuel cell-battery systems - hybrid fuel cell-super capacitor systems.

MODULE V (6 hours)

Battery design for transportation, Mechanical Design and Packaging of Battery Packs for Electric Vehicles, Advanced Battery-Assisted Quick Charger for Electric Vehicles, Charging Optimization Methods for Lithium-Ion Batteries, Thermal run-away for battery systems, Thermal management of battery systems, State of Charge and State of Health Estimation Over the Battery Lifespan, Recycling of Batteries from Electric Vehicles.

Text book:

1. T R Crompton, “Battery Reference Book”, Reed Educational and Professional Publishing Ltd., 2000.
2. James Larminie and John Lowry, “Electric Vehicle Technology Explained”, John Wiley & Sons Ltd., 2003.
3. John Warner, “The Handbook of Lithium Ion Battery Pack Design”, Elsevier Inc., 2015.

4. Aldo V Da Rosa, “Fundamentals of Renewable Energy Processes”, Elsevier Academic Press, 2005.

References:

1. Handbook on Battery Energy Storage System, Asian Development Bank, December 2018.
2. Iqbal Hussain, “Electric and Hybrid Vehicles – Design fundamentals”, CRC Press, 2021.
3. Mehrdad Ehsani, Yimin Gao, Sebastien E. Gay, Ali Emadi, “Modern Electric, Hybrid Electric, and Fuel Cell Vehicles”, CRC Press, 2005.
4. Ali Emadi, “Handbook of Automotive Power Electronics and Motor Drives”, Taylor & Francis, 2005.
5. C C Chan and K T Chau, “Modern Electric Vehicle Technology”, Oxford University Press, 2001.
6. Ali Emadi, “Advance Electric Drive Vehicles”, CRC Press, 2015.
7. NPTEL Lecture notes - “Introduction to Hybrid and Electric Vehicles - Module 9: Energy Storage” https: //nptel.ac.in/content/storage2/courses/108103009/download/M9.pdf
8. NPTEL Video Lecture 03: “Supercapacitors” https://archive.nptel.ac.in/courses/113/105/113105102/
9. NPTEL Video Lecture: Battery pack development, Part 2: https://www.youtube.com/watch?v=ArkO0u1Q3co

COURSE PLAN		
No.	**Topic**	**No. of Lectures**
1	**MODULE I (6 hours)**	
1.1	Need of energy storage, different types of energy storage. Potential energy: Pumped hydro storage. Compressed gas system: Compressed air energy storage.	1
1.2	Kinetic energy: Flywheel storage operation, principles of flywheels, power capacity of flywheel systems, flywheel technologies.	1
1.3	Fossil fuels and synthetic fuels, Solar ponds for energy storage	1
1.4	Electrical and magnetic energy storage: Capacitors, electromagnets.	1
1.5	Chemical energy storage: Thermo-chemical, photo-chemical, bio-chemical, electro-chemical systems.	1
1.6	Comparison of energy storage technologies, Hybridization of energy storages.	1
2	**MODULE II (11 hours)**	
2.1	Fundamental concepts of batteries: Primary and Secondary batteries, Electrochemical reactions, Thermodynamic voltage, Battery Equivalent circuit.	1
2.2	Battery parameters - storage density, energy density, energy efficiency, charge efficiency, specific energy, specific power, state of charge (SoC), state of health (SoH), state of function (SoF), Measurement of battery performance.	1
2.3	Factors affecting battery cell life cycles - C rate, depth of discharge (DoD)	1
2.4	Battery Technologies: Lead-acid batteries, Nickel-based batteries-Nickel/iron, nickel/cadmium, nickel–metal hydride (Ni–MH), Applications.	1
2.5	Lithium-based batteries: Lithium–polymer (Li–P), lithium-ion (Li-Ion).	1
2.6	Lithium-Cobalt, Phosphate (LiFP) Lithium Manganese Oxide, Lithium Iron	1

2.7	Lithium Nickel Manganese Cobalt Oxide (NMC), Lithium Nickel Cobalt Aluminium Oxide (NCA), Lithium Titanate, Applications	1
2.8	Battery pack development process - Electrical design of battery pack, busbar design.	2
2.9	Battery cell testing, Testing standards, Safety issues.	1
2.10	Charging and discharging of a battery, Charge / Discharge characteristics.	1
3	**MODULE III (7 hours)**	
3.1	Magnetic and Electric Energy Storage Systems: Superconducting magnetic energy storage (SMES) systems, Capacitors.	2
3.2	Ultra-capacitor: Basic principles, equivalent circuit.	1
3.3	Ultra-capacitor technologies: Electrochemical double layer capacitor (EDLC), principle of working, structure, performance and applications,	2
3.4	Role of activated carbon and carbon nano-tubes in performance enhancement.	1
3.5	Comparison of Ultra-capacitor characteristics with batteries - applications	1
4	**MODULE IV (10 hours)**	
4.1	Fuel Cells: Operating principle of fuel cells: Electrode potential and current–voltage curve	1
4.2	Fuel cell reactions with alkaline / acid / molten carbonate / ceramic electrolytes / Methanol fuel cells, Fuel cell system characteristics, Circuit model	1
4.3	Hydrogen as energy carrier, Hydrogen storage, Hydrogen production: Compressed hydrogen, cryogenic liquid hydrogen, metal hydrides.	2
4.4	Fuel cell technologies: alkaline fuel cells (AFC), Phosphoric acid fuel cells (PAFC)	1
4.5	Molten carbonate fuel cells (MCFC), Solid oxide fuel cells (SOFC)	1
4.6	Non-hydrogen fuel cells, Direct methanol fuel cells (DMFC), Proton exchange membrane (PEM) fuel cells.	1
4.7	Rechargeable fuel cells, Applications	1
4.8	Hybrid fuel cell-battery systems, hybrid fuel cell-supercapacitor systems.	2
5	**MODULE V (6 hours)**	
5.1	Battery design for transportation, Mechanical Design and Packaging of Battery Packs for Electric Vehicles	1
5.2	Advanced Battery-Assisted Quick Charger for Electric Vehicles	1
5.3	Charging Optimization Methods for Lithium-Ion Batteries,	1
5.4	Thermal run-away for battery systems, Thermal management of battery systems,	1
5.5	State of Charge and State of Health Estimation Over the Battery Lifespan,	1
5.6	Recycling of Batteries from Electric Vehicles	1

MODEL QUESTION PAPER

FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

221EEE009 ENERGY STORAGE CONCEPTS AND APPLICATIONS

Max. Marks: 60 **Time: 2.5 Hrs.**

Sl.	**Part A (Answer all questions)**	**Marks**
1	Compare the different energy storage techniques citing	(5)

	applications for each type.	
2	A battery has capacity of 4000mAh and a C rating of 10C, then calculate the maximum current the battery can deliver.	(5)
3	Compare the characteristics of Ultra Capacitors with batteries.	(5)
4	Discuss about the major requirements for an electrolyte in a fuel cell.	(5)
5	What are the advantages and disadvantages of using lithium-ion batteries versus solid- state batteries in EV applications?	(5)
	Part B **(Answer any five questions)**	
6	Explain the different types of chemical energy storage systems.	(7)
7	Suppose a Battery Life is defined as 2000 cycles when used in standard conditions. The standard conditions are “charged at 0.5C, discharged at 1 C at 25°C with 0.85 DoD”. Assume that one cycle is counted as 1+x, whenever standard operating conditions are violated. Assume, a. x is 0.25 for every degree variation in temperature(T) from 25°C b. x is 0.5 for every 0.01 increment of DoD (ie., D) from 0.85 c. x is 0.1 for every % increment of charge rate (C) from 0.5C and d. x is 0.05 for every % increment of discharge rate (D) from 1C. Determine the life-cycle of the battery when C, D, T and H are 1.5C, 3C, 45 °C and 0.95 respectively.	(7)
8	Explain with a neat figure, the principle of operation of ultra-capacitors. Draw the equivalent circuit and explain.	(7)
9	List out and discuss the technologies for hydrogen storage.	(7)
10	Compare the different hybrid energy storage systems for EVs.	(7)
11	Portray the fuel cell reactions with alkaline / acid / molten carbonate / ceramic electrolytes and in Methanol fuel cells.	(7)
12	Design a 15kWh battery pack with nominal voltage of 350V using Li Ion cells of	(7)

221EEE010	RENEWABLE ENERGY CONVERSION SYSTEMS	Category	L-T-P-C	YOI
		Program Elective 1	3-0-0-3	2022

Preamble: This course intends to provide in-depth knowledge on various renewable energy conversion systems. This course provides an insight into various electrical machines and power converters and control techniques used in renewable energy applications

Course Prerequisites: Nil

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

CO 1	To provide knowledge about different types of renewable energy systems.
CO 2	To analyze the various electrical Generators used for the Wind Energy Conversion Systems
CO 3	To design a power converter used in renewable energy systems such as AC-DC, DC-DC, and AC-AC converters
CO 4	To understand the importance of standalone, grid-connected, and hybrid operation in renewable energy systems
CO 5	To analyse various maximum power point tracking algorithms

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	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	

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Apply	60%	100	40	60	2.5 hours
Analyse	20%				
Evaluate	20%				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred)	:15 marks
Course based task/Seminar/Data collection and interpretation	:15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.)	:10 marks

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions, with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions, with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks.

SYLLABUS

MODULE I: INTRODUCTION TO RENEWABLE ENERGY SYSTEMS (7 Hours)

Introduction to renewable energy systems: Classification of Energy Sources – Importance of Non-conventional energy sources – Advantages and disadvantages of conventional energy sources – Environmental aspects of energy – Impacts of renewable energy generation on the environment – Qualitative study of renewable energy resources: Ocean energy, Biomass energy, Hydrogen energy, - Solar Photovoltaic (PV), Fuel cells: Operating

principles and characteristics, Wind Energy: Nature of wind, Types, control strategy, operating area.
MODULE II: ELECTRICAL MACHINES FOR WECS (6 Hours)
Electrical machines for wind energy conversion systems (WECS): Review of reference theory fundamentals –Construction, Principle of operation and analysis: Squirrel Cage Induction Generator (SCIG), Doubly Fed Induction Generator (DFIG) – Permanent Magnet Synchronous Generator (PMSG).
MODULE III: POWER CONVERTERS & ANALYSIS OF SOLAR PV SYSTEMS (8 Hours)
Power converters & analysis of solar PV systems: Power Converters: Line commutated converters (inversion-mode) – Boost and buck-boost converters- selection of inverter, battery sizing, array sizing. Analysis: Block diagram of the solar PV systems – Types of Solar PV systems: Stand-alone PV systems, Grid integrated solar PV Systems – Grid connection Issues
MODULE IV: POWER CONVERTERS AND ANALYSIS OF WIND SYSTEMS (7 Hours)
Power converters and analysis of wind systems: Power Converters: Three-phase AC voltage controllers- AC-DC-AC converters: uncontrolled rectifiers, PWM Inverters, Grid-Interactive Inverters – Matrix converter. Analysis: Stand-alone operation of fixed and variable speed WECS-Grid integrated SCIG and PMSG based WECS.
MODULE V: HYBRID RENEWABLE ENERGY SYSTEMS (6 Hours)
Hybrid renewable energy systems: Need for Hybrid Systems- Range and type of Hybrid systems- Case studies of Diesel-PV, Wind-PV, Micro-hydel-PV, Biomass-Diesel systems – Maximum Power Point Tracking (MPPT).
Text book: 1. B.H.Khan “Non-conventional Energy sources “,Tata McGraw-hill Publishing Company, New Delhi, 2017 2. S.N.Bhadra, D. Kastha, & S. Banerjee “Wind Electrical Systems”, Oxford University Press, 2009 3. Rashid. M. H “Power electronics Hand book”, Academic press,2nd Edition, 2006.
References: 1. Rai. G.D, “Non-conventional energy sources”, Khanna publishers, 2010. 2. Rai. G.D,” Solar energy utilization”, Khanna publishers, 5th Edition, 2008. 3. Gray, L. Johnson, “Wind energy system”, prentice hall of india, 1995.

COURSE PLAN

No.	Topic	No. of Lectures
1	**MODULE I (7 hours)**	
1.1	Classification of Energy Sources – Importance of Non-conventional energy sources – Advantages and disadvantages of conventional energy sources	1
1.2	Environmental aspects of energy – Impacts of renewable energy generation on the environment	1
1.3	Qualitative study of renewable energy resources: Ocean energy, Biomass energy, Hydrogen energy, - Solar Photovoltaic (PV), Fuel cells: Operating principles and characteristics	3
1.4	Wind Energy: Nature of wind, Types, control strategy, operating area	2
2	**MODULE II (6 hours)**	
2.1	Construction, Principle of operation and analysis: Squirrel Cage Induction Generator (SCIG)	3
2.2	Construction, Principle of operation and analysis: Doubly Fed Induction Generator (DFIG)	2

2.3	Construction, Principle of operation and analysis: Permanent Magnet Synchronous Generator (PMSG).	2
3	**MODULE III (9 hours)**	
3.1	Power Converters: Line commutated converters (inversion-mode) – Boost and buck-boost converters	3
3.2	Selection of inverter, battery sizing, array sizing	2
3.3	Block diagram of the solar PV systems – Types of Solar PV systems: Stand-alone PV systems	2
3.4	Grid integrated solar PV Systems – Grid connection Issues	2
4	**MODULE IV (10 hours)**	
4.1	Power Converters: Three-phase AC voltage controllers,	2
4.2	AC-DC-AC converters: uncontrolled rectifiers, PWM Inverters	2
4.3	Grid-Interactive Inverters – Matrix converter.	2
4.4	Analysis: Stand-alone operation of fixed and variable speed WECS-Grid	3
5	**MODULE V (7 hours)**	
5.1	Need for Hybrid Systems- Range and type of Hybrid systems-	2
5.2	Case studies of Diesel-PV, Wind-PV, Micro-hydel-PV, Biomass-Diesel systems	3
5.3	Maximum Power Point Tracking (MPPT).	2

MODEL QUESTION PAPER		
FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR		
221EEE010 RENEWABLE ENERGY CONVERSION SYSTEM		
Max. Marks: 60		**Time: 2.5 Hrs.**
Sl.	**Part A** **(Answer all questions)**	**Marks**
1	Discuss advantages and limitations of conventional energy sources.	(5)
2	Explain the principle of operation of SCIG in wind energy conversion system.	(5)
3	Define the terms solar constant, solar altitude angle and solar azimuth angle?	(5)
4	Give a short note on Matrix converter	(5)
5	Explain the need for hybrid energy system.	(5)
	Part B **(Answer any five questions)**	
6	Briefly explain the hydrogen energy system with necessary diagram	(7)
7	(i) What are the factors affecting the site selection of OTEC. (4) (ii)Explain the production of producer gas from biomass. (3)	(7)
8	Draw the schematic diagram of DFIG used in wind energy conversion system explain the working.	(7)
9	With neat sketch Explain different types of solar PV system	(7)
10	Explain the Stand-alone operation of fixed and variable speed WECS-	(7)
11	Briefly explain about selection of inverter, battery size and array sizing of a solar PV system	(7)
12	Explain with neat sketch hybrid systems including Wind and PV	(7)

221EEE011	SENSORS AND INSTRUMENTATION	Category	L-T-P-C	YOI
		Program Elective 1	3-0-0-3	2022

Preamble: This course intends to provide an in-depth knowledge on the fundamental concepts of measurement systems, various types of transducers used in industrial applications, recent advancements and trends in measurement technology, importance of signal conditioning circuits and data acquisition processes in ensuring precise measurements and an exploration of virtual instrumentation

Course Prerequisites: Nil

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

CO 1	Explain the principle, input-output configuration, static and dynamic characteristics of typical measurement systems.
CO 2	Identify a suitable transducer used in industrial measurement applications related to force, pressure, level, flow, acceleration, temperature, displacement, speed, etc
CO 3	Explain the recent trends and advances in the measurement systems
CO 4	Comprehend the role of signal conditioning circuits and data acquisition in measurement systems
CO 5	Explain the concepts of virtual instrumentation

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	3				2	
CO 2	2	3				2	
CO 3	2	3				2	
CO 4	2	3				2	
CO 5	2	3				2	

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Apply	60%	100	40	60	2.5 hours
Analyse	20%				
Evaluate	20%				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred)	:15 marks
Course based task/Seminar/Data collection and interpretation	:15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.)	:10 marks

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions, with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions, with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks.

SYLLABUS
MODULE I (11 hours)
Introduction to measurement systems Review of functional blocks of measurement System-Principles of sensors and transducers – Differences Measurement and Error-Accuracy and precision- Types of errors- Systematic and random errors, propagation of errors- - Design of Zero order and first order systems using mathematical modelling- Time response of first order system using simulation tool. General Transduction Principles for measurement applications Classification of Transducers-Static characteristics: Accuracy, precision, resolution, sensitivity, Linearity-Dynamic characteristics Transduction principle – Resistive, Capacitive, Inductive, Piezoresistive, Piezoelectric, optical, Photovoltaic, Thermoelectric, Acoustic and Hall effect
MODULE II (9 hours)
Principle and operation of typical instruments Resistance Transducer: Potentiometer, strain gauge, resistance thermometer, thermistor, hotwire anemometer. Inductance Transducer: Hall effect transducer, LVDT. Capacitance Transducer: capacitive displacement transducer, practical capacitor pickups Speed measurement - Encoders, Resolvers, R/D Converters, Hall current sensors and current sampling - stroboscopic tachometer -Acceleration measurement: capacitive accelerometer, angular accelerometer, velocity sensor Density measurement: Hydrometer, ultrasonic and sonic densitometer. Viscosity measurement: Capillary viscometer, efflux cup viscometer- Humidity measurement: Dew point hygrometer, electrolytic hygrometer - pH meter
MODULE III (6 hours)
Advanced sensors technologies and applications Opto-electronic sensors, Fiber optic sensor, Magnetic sensors, Digital transducers, LASER based instruments, Ultrasonic sensors, Micro sensors, Bio sensors. Smart sensor systems and applications General architecture of a smart sensor – Self calibration – Wireless sensors- energy harvesting techniques – Web based instrumentation-Applications
MODULE IV (9 hours)
Film sensor: Thick film sensors, Thin film sensors- Semiconductor IC Technology-Micro electro mechanical system (MEMS)- Nano electro mechanical system (NEMS) Signal conditioning and Data Acquisition Signal conditioning circuits-Instrumentation amplifiers- Unbalanced bridge. Bridge linearization using op amp Precision rectifiers, Log amplifiers, Charge amplifiers, Isolation amplifier, bridges, filters, analog-to digital and digital-to-analog conversion, switched capacitor circuits, Phase sensitive detectors, Noise problem in instrumentation and its minimisation Elements of data acquisition system, Virtual instrumentation system: architecture of virtual instruments – Virtual instruments and traditional instruments
MODULE V (5 hours)
Industrial Applications of sensors and instrumentation systems Vibration measurement in machine tools, Position measurement of end effectors in robots -Speed measurement of road wheels in Automotive system, Environmental monitoring and biomedical applications
Text book: 1. Bentley JP, Principles of measurement systems, Pearson Publishers., 2012. 2. Ernest. O. Doebelin, “Measurement System Application & Design”, (2008), McGraw Hill Book co, 5th edition, 2008.
References:

1. D. Patranabis, “Principles of Industrial Instrumentation”, 4th Edition, Tata McGraw Hill, New Delhi,2017
2. John G. Webster, HalitEren, “Measurement, Instrumentation, and Sensors Handbook”, (2014), Second Edition, CRC Press.
3. Patranabis.D, “Sensors and Transducers”, 2nd Edition, Prentice Hall of India, 2021
4. H.R. Taylor, “Data Acquisition for Sensor Systems”, (2013), Springer Science & Business Media.
5. R. K. Jain, “Mechanical and Industrial Measurements”, 12th Edition, Khanna publishers, 2015.
6. Randy Frank, Understanding Smart Sensors, Artec House Boston. London, 2000
7. K. Krishnaswamy, S.Vijayachitra, “Industrial Instrumentation”, 2nd Edition, New age International Private limited, 2011.
8. Microsensors, Muller, R.S., Howe, R.T., Senturia, S.D., Smith, R.L., and White, R.M. [Eds.], IEEE Press, New York, NY, 1991.

COURSE PLAN

No.	Topic	No. of Lectures
1	**MODULE I: Introduction to Measurement Systems (11 hours)**	
1.1	Introduction to measurement systems	1
1.2	Review of functional blocks of measurement System	1
1.3	Principles of sensors and transducers	2
1.4	Differences Measurement and Error-Accuracy and precision- Types of errors- Systematic and random errors, propagation of errors	2
1.5	Design of Zero order and first order systems using mathematical modelling- Time response of first order system using simulation tool.	1
1.6	General Transduction Principles for measurement applications Classification of Transducers-Static characteristics: Accuracy, precision, resolution, sensitivity, Linearity-Dynamic characteristics	2
1.7	Transduction principle – Resistive, Capacitive, Inductive, Piezoresistive, Piezoelectric, optical, Photovoltaic, Thermoelectric, Acoustic and Hall effect	2
2	**MODULE II: Principles & Operation of Typical Instruments (9 hours)**	
2.1	Resistance Transducer: Potentiometer, strain gauge, resistance thermometer, thermistor, hotwire anemometer.	2
2.2	Inductance Transducer: Hall effect transducer, LVDT.	1
2.3	Capacitance Transducer: capacitive displacement transducer, practical capacitor pickups	1
2.4	Speed measurement - Encoders, Resolvers, R/D Converters, Hall current sensors and current sampling - stroboscopic tachometer - Acceleration measurement: capacitive accelerometer, angular accelerometer, velocity sensor	2
2.5	Density measurement: Hydrometer, ultrasonic and sonic densitometer. Viscosity measurement: Capillary viscometer, efflux cup viscometer	2
2.6	Humidity measurement: Dew point hygrometer, electrolytic hygrometer - pH meter	1
3	**MODULE III: Advanced Sensor Technologies and Applications (6 hours)**	
3.1	Opto-electronic sensors, Fiber optic sensor, Magnetic sensors	1
3.2	Digital transducers, LASER based instruments	1
3.3	Ultrasonic sensors, Micro sensors, Bio sensors	2

3.4	Smart sensor systems and applications General architecture of a smart sensor – Self calibration – Wireless sensors- energy harvesting techniques – Web based instrumentation-Applications	2
4	**MODULE IV: Film Sensors and Signal Conditioning (9 hours)**	
4.1	Film sensor: Thick film sensors, Thin film sensors	2
4.2	Semiconductor IC Technology	1
4.3	Micro electro mechanical system (MEMS)- Nano electro mechanical system (NEMS)	2
4.4	Signal conditioning circuits-Instrumentation amplifiers-Unbalanced bridge. Bridge linearization using op amp Precision rectifiers, Log amplifiers, Charge amplifiers, Isolation amplifier, bridges, filters, analog- to digital and digital-to-analog conversion, switched capacitor circuits, Phase sensitive detectors, Noise problem in instrumentation and its minimisation	3
4.5	Elements of data acquisition system, Virtual instrumentation system: architecture of virtual instruments – Virtual instruments and traditional instruments.	1
5	**MODULE V: Industrial Applications of Sensors & Instrumentation Systems (5 hours)**	
5.1	Vibration measurement in machine tools	1
5.2	Position measurement of end effectors in robots	1
5.3	Speed measurement of road wheels in Automotive system	1
5.4	Environmental monitoring and biomedical applications	2

MODEL QUESTION PAPER

FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

221EEE011 SENSORS AND INSTRUMENTATION

Max. Marks: 60 **Time: 2.5 Hrs.**

Sl.	**Part A** **(Answer all questions)**	**Marks**
1	Define the following terms in measurement i) Accuracy ii) Resolution iii) Precision. What are the different standards of measurements?	(5)
2	Explain the principle of operation of a resistance thermometer (RTD). How does it differ from a thermistor in terms of temperature measurement?	(5)
3	Explain the working principle of a magnetic sensor and its applications in the automotive industry.	(5)
4	What are the fundamental principles behind MEMS technology, and how does it integrate mechanical and electrical components?	(5)
5	What are the key factors to consider when selecting sensors for industrial applications, and how do these factors influence sensor performance?	(5)
	Part B **(Answer any five questions)**	
6	Explain the principle of transduction and compare the different types of transducers based on their working principles	(7)
7	Describe the working principle of an LVDT. How does it measure linear displacement	(7)
8	Explain the working principle of encoders for speed measurement. How do optical and magnetic encoders differ in their operation?	(7)

9	Explain the principle of operation of ultrasonic sensors. How are ultrasonic sensors utilized in automotive parking assistance systems, and what are their limitations?	(7)
10	Discuss the function of an unbalanced bridge in signal conditioning and how it can be linearized using an op-amp.	(7)
11	Discuss the significance of switched capacitor circuits in analog-to-digital conversion.	(7)
12	Describe the different types of sensors used for position measurement of end effectors in robotic systems.	(7)

221EEE026	ANALYSIS OF AUTOMOTIVE STRUCTURES	Category	L-T-P-C	YOI
		Program Elective 2	3-0-0-3	2022

Preamble: This course aims to provide the fundamental engineering knowledge required for the static and dynamic analysis of automotive structure. The first module covers the analysis of stress and strain which demonstrates the theoretical formulation of various concepts related to stress and strain under different loading conditions. The second module covers the constitutive equations and analysis of 2D problems in Cartesian coordinate system. The principle of various energy methods for solving complicated solid mechanics problem are covered in the third module. The fourth module covers the review vibratory model formulation of the single -degree of freedom system. The multi degree of freedom system and response to Arbitrary and non- harmonic excitations are covered in the fifth module.

Course Prerequisites: Nil

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

CO 1	To analyse stress and strain of general elastic body
CO 2	Formulate stress-strain constitutive relation and analyse 2-D elasticity problem
CO 3	To apply various energy methods to solve elasticity problem
CO 4	Formulate and analyse a mathematical model for a vibratory system
CO 5	Analyse the vibratory model of Multi Degree of Freedom systems.

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3		1	2		2	
CO 2	3		1	2		2	
CO 3	2		1	2		2	
CO 4	3		2	2		2	
CO 5	2		2	2		2	

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Apply	30%	100	40	60	2.5 hours
Analyse	50%				
Evaluate	20%				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred)	:15 marks
Course based task/Seminar/Data collection and interpretation	:15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.)	:10 marks

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions, with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions, with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks.

SYLLABUS
MODULE I
Stress and Strain Analysis Static analysis of automotive structure- Three-Dimensional Stress analysis: State of stress at point- stress tensor, Traction, Cartesian- polar coordinate system- Cauchy's equation , Principal stresses and planes, Stress transformation, Equilibrium equation- equality of cross shear; Analysis of strain- displacement field, strain at appoint -strain tensor- Principal strains and planes, strain displacement-relations compatibility equations.
MODULE II
Stress-strain constitutive relation and analyse 2-D elasticity problem Constitutive equations – stress-strain relations of isotropic material, Lame's coefficients, relation between elastic constants, boundary conditions, Saint Venant's principle- Two dimensional problems in Elasticity- Plane stress problems- Plane stress and Pane strain-compatibility equations. Airy's stress function-compatibility equation in stress function-polynomial method of solution.
MODULE III
Energy methods Theories of Failure, and their Applications - Energy Methods –Strain energy of linear elastic deformation, Energy Theorems, Principal of virtual work. Principal of minimum potential energy, complementary strain energy, Crotti-Engesser's theorem, Castigliano's first and second theorem, reciprocal relation and Maxwell's reciprocal theorem
MODULE IV
Single- and two-degree freedom of vibratory system Dynamic Analysis of automotive structure- -Sources of Vibration-Mathematical Models-Review of Single Degree Freedom Systems - Free and forced vibrations, base excitation. Two degree of freedom systems-Normal mode vibration-Principal co-ordinates-Coordinate coupling.
MODULE V
Multi degree of freedom and response to Arbitrary and non- harmonic excitations Multi Degree Freedom System –Influence Coefficients, Modal Analysis, Eigen Values and Eigen Vectors. Orthogonality of mode shapes, General response of multi degree of freedom systems. Response to Arbitrary and non- harmonic excitations –Duhamel Integral, Transient Vibration, Impulsive step & pulse load response
Text book:
References: 1. Advanced Mechanics of solids by L S Srinath, Mc Graw Hill 2. Advanced Mechanics of solids by S Anil Lal, Sivas Publications 3. Grover G K," Mechanical Vibrations", Nem Chand and Bros,2009 2. Rao, S.S.," Mechanical Vibrations," Pearson Education; Sixth edition ,25 June 2018

COURSE PLAN		
No.	**Topic**	**No. of Lectures**
1	**MODULE I (8 hours)**	
1.1	Introduction to stress analysis	1
1.2	Resisting traction and stress at a point in Cartesian co-ordinate-stress tensor	1
1.3	Coordinate transformation- Cartesian to polar- Cauchys equation	1
1.4	Principal stresses and planes, Stress transformation	1
1.5	Equilibrium equation- equality of cross shear; Analysis of strain	1
1.6	displacement field, strain at appoint -strain tensor	1
1.7	Principal strains and planes	1
1.8	strain displacement-relations compatibility equations.	1

2	**MODULE II (8 hours)**	
2.1	Constitutive equations – stress-strain relations of isotropic material,	1
2.2	Lame's coefficients, relation between elastic constants	1
2.3	boundary conditions, Saint Venant's principle	1
2.4	Two dimensional problems in Elasticity- Plane stress and Plane strain problems	1
2.5	Plane stress and Pane strain- compatibility equations	1
2.6	Airy's stress function-	1
2.7	compatibility equation in stress function	1
2.8	polynomial method of solution	1
3	**MODULE III (8 hours)**	
3.1	Theories of Failure, and their Applications	1
3.2	Energy Methods –Strain energy of linear elastic deformation	1
3.3	Energy Theorems, Principal of virtual work	1
3.4	Principal of minimum potential energy, complementary strain energy	1
3.5	Crotti-Engesser's theorem, Castigliano's first and second theorem	2
3.6	reciprocal relation and Maxwell's reciprocal theorem	2
4	**MODULE IV (8 hours)**	
4.1	Review of Single Degree Freedom Systems	2
4.2	Free and forced vibrations & base excitation.	2
4.3	Two degree of freedom systems-Normal modes of vibration	3
4.4	Principal co-ordinates-Coordinate coupling	1
5	**MODULE V (8 hours)**	
5.1	Introduction to Multi Degree Freedom System	1
5.2	Modal Analysis, Eigen Values and Eigen Vectors, Orthogonality of mode shapes.	2
5.3	General response of multi degree of freedom systems	2
5.4	Response to Arbitrary and non- harmonic excitations –Duhamel Integral,	2
5.5	Vibration, Impulsive step & pulse load response	1

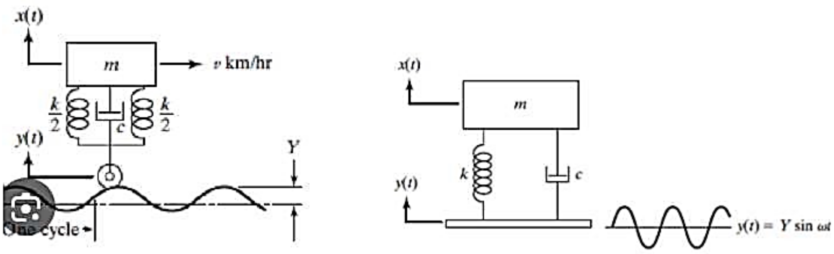
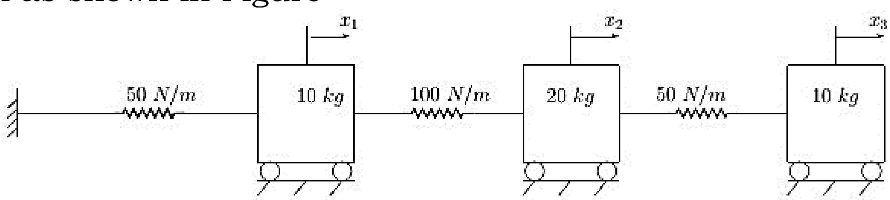
MODEL QUESTION PAPER

FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

221EEE026 ANALYSIS OF AUTOMOTIVE STRUCTURES

Max. Marks: 60 **Time: 2.5 Hrs.**

Sl.	**Part A (Answer all questions)**	**Marks**
1	The state of stress at appoint is characterised by the matrix in which x is unknown. Find the value of unknown x when one of the principal stress is zero and also find the direction cosines of the normal to this plane. $\begin{bmatrix} x & 2 & 1 \\ 2 & 0 & 2 \\ 1 & 2 & 0 \end{bmatrix}$	(5)
2	Evaluate the Lame's coefficients λ and μ for Aluminium with E =70 G pa and ν =0.3	(5)
3	A cantilever is subjected to load P at its free end. Find the transverse deflection of the beam its two third span using reciprocal relation.	(5)
4	A 200 kg machine is placed at the end of 1.8 m long steel. The	(5)

	machine is observed to vibrate with a natural frequency of 21 Hz. What is the moment of inertia of the beam about its neutral axis? Take E= 210x 10^9 N/m2	
5	Define the orthogonality of normal modes, generalized mass and stiffness	(5)
	Part B **(Answer any five questions)**	
6	What is Cauchy's equation? Derive the traction's components in an arbitrary plane.	(7)
7	For the given tensorial strain at a point on an iron object with E = 210 × 10^6 kPa and G = 80 × 10^6 kPa, determine the stress matrix. $\begin{bmatrix} 6 & \frac{1}{2} & 3 \\ \frac{1}{2} & 0 & \frac{3}{2} \\ 3 & \frac{3}{2} & 0 \end{bmatrix} \times 10^{-3}$	(7)
8	Differentiate between linear and nonlinear elastic deformation. Write down the energy theorems valid for each.	(7)
9	Determine the strain energy of a steel object with E= 210 kg/m3 and G=75 x10^6 kpa. The tensorial strain at a point is given as $\begin{bmatrix} 0.5 & 0 & -0.5 \\ 0 & -1.5 & 1.5 \\ -1 & 1.5 & 0 \end{bmatrix} \times 10-3$	(7)
10	The given figure shows a simple model of a motor vehicle that can vibrate in the vertical direction while traveling over a rough road. The vehicle has a mass of 1200 kg. The suspension system has spring constant of 400 kN/m and damping ratio is 0.5 and vehicle speed is 20 km/hr. The road surface varies sinusoidally with an amplitude of Y=0.05 m and wavelength of 6 m. Find a) frequency ratio b) displacement amplitude of the vehicle. 	(7)
11	Find influence coefficient matrices and dynamic matrix of the given system as shown in Figure 	(7)
12	Derive the equation of response when the single degree of freedom subjected to impulse force.	(7)

221EEE033	THERMAL MANAGEMENT OF ELECTRIC VEHICLES	Category	L-T-P-C	YOI
		Program Elective 2	3-0-0-3	2022

Preamble: This course delves into the intricate realm of thermal management in electric vehicles, covering essential concepts such as heat transfer modes, cabin climate control, battery thermal management systems, and advanced cooling technologies. Through theoretical insights, practical applications, and experimental investigations, students will gain a holistic understanding of optimizing thermal performance in the evolving landscape of electric vehicle engineering.

Course Prerequisites: Nil

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

CO 1	Analyse steady-state and transient conduction, evaluate convective processes, and understand non-dimensional numbers' significance.
CO 2	Comprehend fin equations, heat sink design, and advanced cooling technologies, applying them effectively in electric vehicle thermal management.
CO 3	Understand thermal comfort, vehicle indoor climate, HVAC principles, and integration of air conditioning systems in vehicle cabins.
CO 4	Apply battery thermal management techniques, understand thermal issues, and predict temperature distribution using modeling, preparing for future technologies.
CO 5	Develop numerical models, conduct simulations and experiments, and set up vehicle-level experimentation for battery thermal management systems.

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3		2	3		2	
CO 2	3		2	3		2	
CO 3	3		3	3		3	
CO 4	3		3	3		3	
CO 5	3		3	3		3	

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Apply	60%	100	40	60	2.5 hours
Analyse	20%				
Evaluate	20%				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred)	:15 marks
Course based task/Seminar/Data collection and interpretation	:15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.)	:10 marks

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions, with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions, with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks.

SYLLABUS

MODULE I

Introduction to heat transfer- modes of heat transfer- basic laws of heat transfer- importance of various thermo- physical properties- combined heat transfer mechanism. One dimensional steady state heat conduction – analysis of plane wall, cylindrical and spherical configurations - thermal resistance- critical radius- conduction with heat generation. Transient conduction. Convection heat transfer: Newton's law of cooling- Laminar and Turbulent flow- Free and forced convection for internal and external configurations- Importance of various non- dimensional numbers.

MODULE II

Fins and Heat Sinks: Fin Equation, Infinitely Long Fin, Adiabatic Fin Tip, Convection and Radiation from Fin Tip, Constant Temperature Fin Tip, Fin Thermal Resistance, Effectiveness, and Efficiency with Variable Cross Sections. Heat Sink Thermal Resistance, Effectiveness, and Efficiency, Advanced Cooling Technologies in EVs: Heat Pipe Applications in Electronic Cooling, Thermosyphons, Liquid Cooling. Phase Change Materials.

MODULE III

Cabin Climate Control: Definition of Thermal Comfort, Human Thermo-Physiology, Body Energy Balance, Skin Sensible Losses and Latent Losses, Respiratory Losses. Vehicle Indoor Climate - Mean Radiant Temperature, Operative Temperature, Equivalent Temperature, Local and Whole-Body Equivalent Temperature. Control of Vehicle Indoor Climate and Air Stratification. Evaluation of Thermal Comfort - PMV Approach, Cabin Thermal Loads- Energy Transfer Mechanisms Involved in a Vehicle Cabin, Heat Transfer Through the Cabin Body - Heat Transfer Through the Glazing. Ventilation - Internal Gains, HVAC Unit Components and Working Principle, Working Principle of a Vapor-Compression Refrigerator - Integration of the Air-Conditioning Loop into the Vehicle.

MODULE IV

Battery thermal management systems: Liquid cooling systems, Air cooling systems, Phase change materials (PCM) and their role in thermal management. Comparison of different thermal management approaches, Thermal issues associated with lithium-ion batteries. Factors influencing battery temperature. Strategies for battery thermal management: active cooling, passive cooling, and thermal insulation. Future BTM Technologies. Thermal modeling and simulation techniques for predicting battery temperature distribution. Case studies of battery thermal management systems implemented in commercial electric vehicles.

MODULE V

Simulation and Experimental Investigation of Battery TMSs: Numerical Model Development for Cell and Submodules, Numerical Study of PCM Application, Initial and Boundary Conditions and Model Assumptions, Material Properties and Model Input Parameters, Governing Equations and Constitutive Laws, Model Development for Simulations. Simulations and Experimentations on Cell Level, Submodule Level. Instrumentation of the Cell, Submodule, Heat Exchanger. Preparation of PCMs and Nano-Particle Mixtures. Setting up the Test Bench. Vehicle Level Experimentation Set Up and Procedure- Setting Up the Data Acquisition Hardware and Software. Vehicle Level Experimentations.

Text book:

1. Dincer, I., Hamut, H.S. and Javani, N., 2016. Thermal management of electric vehicle battery systems. John Wiley & Sons.
2. Bergman, T.L., Lavine, A.S., Incropera, F.P. and DeWitt, D.P., 2011. Introduction to heat transfer. John Wiley & Sons.

References:

1. Lemort, Vincent, Gérard Olivier, and Georges de Pelsemaeker. Thermal Energy Management in Vehicles. John Wiley & Sons, 2023.
2. Younes Shabany," Heat Transfer: Thermal Management of Electronics" 2010, CRC

Press

COURSE PLAN		
No.	**Topic**	**No. of Lectures**
1	**MODULE I (8 hours)**	
1.1	Introduction to heat transfer- modes of heat transfer- basic laws of heat transfer- importance of various thermo-physical properties-combined heat transfer mechanism.	2
1.2	One dimensional steady state heat conduction – analysis of plane wall, cylindrical and spherical configurations	2
1.3	thermal resistance- critical radius- conduction with heat generation. Transient conduction.	2
1.4	Convection heat transfer: Newton's law of cooling- Laminar and Turbulent flow- Free and forced convection for internal and external configurations-	1
1.5	Importance of various non-dimensional numbers	1
2	**MODULE II (8 hours)**	
2.1	Fins and Heat Sinks: Fin Equation, Infinitely Long Fin, Adiabatic Fin Tip, Convection and Radiation from Fin Tip,	3
2.2	Constant Temperature Fin Tip, Fin Thermal Resistance, Effectiveness, and Efficiency with Variable Cross Sections.	2
2.3	Heat Sink Thermal Resistance, Effectiveness, and Efficiency,	1
2.4	Advanced Cooling Technologies in EVs: Heat Pipe Applications in Electronic Cooling, Thermosyphons,	1
2.5	Liquid Cooling. Phase Change Materials.	1
3	**MODULE III (9 hours)**	
3.1	Cabin Climate Control: Definition of Thermal Comfort, Human Thermo- Physiology, Body Energy Balance, Skin Sensible Losses and Latent Losses, Respiratory Losses.	1
3.2	Vehicle Indoor Climate - Mean Radiant Temperature, Operative Temperature, Equivalent Temperature, Local and Whole-Body Equivalent Temperature. Control of Vehicle Indoor Climate and Air Stratification.	2
3.3	Evaluation of Thermal Comfort - PMV Approach, Cabin Thermal Loads- Energy Transfer Mechanisms Involved in a Vehicle Cabin,	2
3.4	Heat Transfer Through the Cabin Body - Heat Transfer Through the Glazing. Ventilation - Internal Gains,	2
3.5	HVAC Unit Components and Working Principle, Working Principle of a Vapor- Compression Refrigerator - Integration of the Air-Conditioning Loop into the Vehicle.	2
4	**MODULE IV (9 hours)**	
4.1	Battery thermal management systems:Liquid cooling systems, Air cooling systems, Phase change materials (PCM) and their role in thermal management.	2
4.2	Comparison of different thermal management approaches, Thermal issues associated with lithium-ion batteries.	2
4.3	Factors influencing battery temperature. Strategies for battery thermal management: active cooling, passive cooling, and thermal insulation. Future BTM Technologies.	2
4.4	Thermal modeling and simulation techniques for predicting battery temperature distribution.	1
4.5	Case studies of battery thermal management systems implemented	2

	in commercial electric vehicles.	
5	**MODULE V (8 hours)**	
5.1	Simulation and Experimental Investigation of Battery TMSs: Numerical Model Development for Cell and Submodules	2
5.2	Numerical Study of PCM Application, Initial and Boundary Conditions and Model Assumptions, Material Properties and Model Input Parameters, Governing Equations and Constitutive Laws,	2
5.3	Model Development for Simulations. Simulations and Experimentations on Cell Level, Submodule Level. Instrumentation of the Cell, Submodule,	2
5.4	Heat Exchanger. Preparation of PCMs and Nano-Particle Mixtures	1
5.5	Vehicle Level Experimentation Set Up and Procedure- Setting Up the Data Acquisition Hardware and Software. Vehicle Level Experimentations.	1

MODEL QUESTION PAPER		
FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR		
221EEE033 THERMAL MANAGEMENT OF ELECTRIC VEHICLES		
Max. Marks: 60		**Time: 2.5 Hrs.**
Sl.	**Part A** **(Answer all questions)**	**Marks**
1	In a thermal insulation project, you need to determine whether adding more insulation to a cylindrical pipe will increase or decrease the heat loss. How would you apply the concept of the critical radius to decide the optimal thickness of insulation?	(5)
2	Given the need to manage high heat flux in electric vehicles, how would you integrate phase change materials (PCMs) into the design of a heat sink? What considerations would you make regarding the heat sink's thermal resistance and the PCM's melting point?	(5)
3	Design a ventilation strategy to minimize air stratification in a vehicle cabin. How would you ensure uniform temperature distribution, and what methods would you use to evaluate the effectiveness of your design?	(5)
4	What thermal issues are most critical in lithium-ion batteries, and how would you address these in the design of a thermal management system for a high-performance electric vehicle?	(5)
5	How would you develop a numerical model for predicting the thermal behavior of a battery cell and its submodules under different operating conditions? Discuss the selection of material properties, model input parameters, and assumptions that would ensure the model's accuracy and reliability.	(5)
	Part B **(Answer any five questions)**	
6	How would you use Reynolds, Prandtl, and Nusselt numbers to evaluate and compare the heat transfer performance in forced convection across a flat plate and in a pipe? Discuss the implications for both laminar and turbulent flow conditions.	(7)
7	How would you evaluate the performance of a fin with a varying cross-sectional area under different boundary conditions (e.g., adiabatic tip, constant temperature tip)? What role does the fin's effectiveness and efficiency play in this evaluation?	(7)
8	Evaluate the performance of different materials (e.g., aluminum, copper, and graphite) used in the construction of heat sinks for	(7)

	EV power electronics. Consider factors such as thermal conductivity, weight, cost, and manufacturability in your assessment.	
9	How does human thermo-physiology influence the settings of a vehicle's climate control system? Discuss how understanding body energy balance can lead to better climate control strategies.	(7)
10	Analyze a case study of a commercial electric vehicle with a specific battery thermal management system. What lessons can be learned from its design and implementation, and how could these lessons be applied to future EV models?	(7)
11	Analyze the effectiveness of various cooling strategies (liquid cooling, air cooling, and PCM-based cooling) for battery thermal management in terms of heat dissipation, temperature uniformity, and energy efficiency. What are the trade-offs involved in choosing one approach over the others?	(7)
12	Analyze the potential sources of error in the instrumentation of a battery cell, submodule, and heat exchanger during thermal management experiments. How would inaccuracies in temperature measurement or data acquisition affect the interpretation of experimental results?	(7)

221EEE034	SIMULATION AND ANALYSIS OF FLUID FLOW AND HEAT TRANSFER PHENOMENA	Category	L-T-P-C	YOI
		Program Elective 2	3-0-0-3	2022

Preamble: This course helps the students to develop an understanding of computational fluid dynamics and provides an opportunity to practice numerical solution techniques as applied to the equations governing fluid mechanics and heat transfer. The emphasis of this course will be on the fundamental principles that govern the implementation of CFD in practical applications.

Course Prerequisites: Nil

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

CO 1	Apply governing equations of fluid flow and heat transfer based on the mathematical and physical nature of the problem.
CO 2	Use finite difference methods to discretize differential equations and analyse the discretized equations.
CO 3	Use finite volume and finite difference methods to solve heat transfer problems.
CO 4	Apply finite volume method to diffusion and convection problems and analyse various difference schemes.
CO 5	Solve 2D and 3D incompressible viscous flow problems using numerical methods.

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3		2	3		2	
CO 2	3		2	3		2	
CO 3	3		3	3		3	
CO 4	3		3	3		3	
CO 5	3		3	3		3	

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Apply	60%	100	40	60	2.5 hours
Analyse	20%				
Evaluate	20%				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred) :15 marks
Course based task/Seminar/Data collection and interpretation :15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.) :10 marks

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions, with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions, with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks.

SYLLABUS

MODULE I

Governing equations of fluid mechanics and heat transfer; fundamental equations – continuity equation, momentum equation and energy equation; non-dimensional form of equations; boundary layer equations for steady incompressible flows. Physical and mathematical classifications of partial differential equations. Comparison of experimental, theoretical and numerical approaches; applications of CFD.

MODULE II

Discretization-converting derivatives to their finite difference forms-Taylor's series approach, polynomial fitting approach; forward, backward and central differencing Schemes. Discretization error, truncation error, round off error. Consistency and numerical stability, iterative convergence, condition for convergence, rate of convergence; under and over relaxations, termination of iteration.

MODULE III

Finite volume method for Steady one–dimensional conduction problems; dealing with nonlinearities; two-dimensional steady state conduction problems; point-by-point and line-by-line method of solution; dealing with Dirichlet, Neumann, and Robins type boundary conditions; tri-diagonal matrix algorithm; transient heat conduction problems - explicit, implicit, Crank-Nicholson and ADI schemes.

MODULE IV

Finite volume method for diffusion and convection-diffusion problems; steady one-dimensional convection and diffusion; upwind, hybrid, power-law and QUICK schemes; false diffusion. Introduction to Turbulence and its modeling – DNS and LES.

MODULE V

Computation of the flow field using stream function-vorticity formulation. 2D incompressible viscous flow. Primitive-variable approach. Staggered grid. Pressure correction methods. Solution algorithm for pressure-velocity coupling in steady flows-SIMPLE algorithm. Boundary conditions for the pressure correction method. Modeling of Multiphase problems – enthalpy, VOF and Level Set Methods. Computer graphics techniques to present CFD results. Projects/ Exercises: Simulations to analyze cooling Systems for Electric Vehicle Batteries and motors - optimize vehicle aerodynamics-Battery Pack Cooling and Heating Systems - Impact of Fluid Dynamics on Vehicle Range and Performance - Multi-Physics Simulation for Electric Vehicle Components.

Text book:

1. Anderson, D, A, Tannehill, J C, and R H Pletcher, R H, Computational Fluid Mechanics and Heat Transfer, Second Edition, Taylor & Francis, 1995
2. Muralidhar, K and T Sundararajan (eds.) Computational Fluid flow and Heat Transfer, Second Edition, Narosa Publishing House, 2003.
3. Versteeg, H K and W Malalasekera, W, An Introduction to Computational Fluid Dynamics: The Finite Volume method, Addison Wesley-Longman, 1995
4. Patankar, S, V, Numerical Heat Transfer and Fluid Flow, Hemisphere, 1980.

References:

1. Klaus A. Hoffmann, Steve T Chiang, Computational Fluid Dynamics, Fourth Edition, Volume 1, Engineering Education System, 2000.
2. Hornbeck, R W, Numerical Marching Techniques for Fluid Flows with Heat Transfer, NASA, SP -297, 1973.
3. Computational Fluid Dynamics: The Basics with Applications – John D Anderson, Jr, McGraw-Hill, 1995
4. Computational Methods for Fluid Dynamics - Joel H. Ferziger and Milovan Peric. Springer

COURSE PLAN

No.	Topic	No. of Lectures
1	**MODULE I (7 hours)**	
1.1	Governing equations of fluid mechanics and heat transfer; fundamental equations	1
1.2	Continuity equation, momentum equation and energy equation;	2
1.3	Non-dimensional form of equations	1

1.4	Boundary layer equations for steady incompressible flows.	1
1.5	Physical and mathematical classifications of partial differential equations.	1
1.6	Comparison of experimental, theoretical and numerical approaches; applications of CFD.	1
2	**MODULE II (8 hours)**	
2.1	Discretization-converting derivatives to their finite difference forms-Taylor's series approach and polynomial fitting approach	2
2.2	Forward, backward and central differencing Schemes.	2
2.3	Discretization error, truncation error, round off error	1
2.4	Consistency and numerical stability	1
2.5	Iterative convergence, condition for convergence, rate of convergence	1
2.6	Under and over relaxations, termination of iteration.	1
3	**MODULE III (9 hours)**	
3.1	Finite volume method for steady one–dimensional conduction problems	1
3.2	handling of boundary conditions;	1
3.3	two-dimensional steady state conduction problems; point-by-point and line-by-line method of solution;	2
3.4	dealing with Dirichlet, Neumann, and Robins type boundary conditions;	1
3.5	tri-diagonal matrix algorithm;	1
3.6	transient heat conduction problems -explicit, implicit, Crank-Nicholson schemes	2
3.7	ADI scheme	1
4	**MODULE IV (7 hours)**	
4.1	Finite volume method for diffusion and convection-diffusion problems;	1
4.2	Upwind scheme for steady one-dimensional convection and diffusion	2
4.3	Hybrid scheme and power-law scheme	2
4.4	QUICK scheme	2
4.5	Numerical false diffusion, Introduction to Turbulence and its modeling – DNS and LES.	1
5	**MODULE V (8 hours)**	
5.1	Computation of the flow field using stream function-vorticity formulation.	1
5.2	One & Two-dimensional incompressible viscous flow. Primitive-variable approach.	1
5.3	Staggered grid. Pressure correction methods.	1
5.4	Solution algorithm for pressure-velocity coupling in steady flows-SIMPLE algorithm, Boundary conditions for the pressure correction method.	1
5.5	Modeling of Multiphase problems – enthalpy, VOF and Level Set Methods.	1
5.6	Computer graphics techniques to present CFD results.	1
5.7	Simulations to analyze cooling Systems for Electric Vehicle Batteries and motors - optimize vehicle aerodynamics- Battery Pack Cooling and Heating Systems	1
5.8	Impact of Fluid Dynamics on Vehicle Range and Performance - Multi- Physics Simulation for Electric Vehicle Components.	1

MODEL QUESTION PAPER		
FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR		
221EEE034 SIMULATION AND ANALYSIS OF FLUID FLOW AND HEAT TRANSFER PHENOMENA		
Max. Marks: 60		Time: 2.5 Hrs.
Sl.	**Part A (Answer all questions)**	**Marks**
1	Compare parabolic, hyperbolic and elliptic partial differential equations in a numerical perspective.	(5)
2	The equation for deflection of a beam is given by $\frac{d^2y}{dx^2} - e^{x^2} = 0$ and deflection at x = 0 and x = 1 are given by $y(0) = 0$ and $y(1) = 0$. Use the difference equations to find the approximate deflection at x = 0.25,0.5, and 0.75.	(5)
3	Consider the problem of source-free heat conduction in an insulated rod of 0.5 m length whose ends are maintained at constant temperatures of 100°C and 500°C respectively. The one-dimensional problem is governed by $\frac{d}{dx}\left(\frac{k*dT}{dx}\right) = 0$. Calculate the steady state temperature distribution in the rod using finite volume method. Thermal conductivity K equals 1000 W/m.K, cross-sectional area A is 10×10^{-3} m^2. Use cell centered grid points.	(5)
4	Differentiate central differencing scheme with upwind differencing scheme to analyse the influence of numerical false diffusion.	(5)
5	It is desired to calculate boundary layer development over a bullet spinning with angular velocity Ω and moving with velocity U_0. Write the governing equations and the boundary conditions at the inlet and exit boundaries for this problem. Clearly state the assumptions and provide an algorithm to solve the problem.	(5)
	Part B (Answer any five questions)	
6	Show the Navier-Stokes equations in vector form by clearly mentioning the solution vector, flux vector and source vector. Convert the Navier-Stokes equations into non-dimensional form.	(7)
7	Consider the viscous flow of air over a flat plate. At a given station in the flow direction, the variation of the flow velocity, u, in the direction perpendicular to the plate (the y direction) is given by the expression $u = 21582\left(1 - e^{\left(\frac{-y}{L}\right)}\right)$, where L = characteristic length = 0.05 m. The unit of u is m/s. The viscosity coefficient μ = 1.81×10^{-5} kg/(m.s). Using the equation for u, find the values of u at discrete grid points equally spaced in the y direction with $\Delta y = 0.002m$. With the values obtained at discrete grid points located at y = 0, 0.002 m, 0.004 m, and 0.006 m, calculate the shear stress at the wall rw(a) using a first order difference equation and (b) second order difference equation. Compare these calculated finite difference results with the exact value of tau-w which can be found by making use of the expression for u.	(7)
8	A semi-infinite solid is initially at 25°C. At t = 0, the solid surface (x = 0) is suddenly exposed to a heat source of 10 kW/m². A thermocouple is placed at x = 1 mm to apparently measure the	(7)

9	surface temperature. Compute the temperature distribution in the solid as a function of x and t and estimate the error in the thermocouple reading as a function of time. Given K = 80 W/m-K, ρ = 7, 870 kg/m^3, and C = 450 J/kg-K.	
9	Two plastic sheets, each 5 mm thick, are to be bonded together with a thin layer of adhesive that fuses at 140^{o}C. For this purpose, they are pressed between two surfaces at 250^{o}C. Using finite volume method, determine the time for which the two sheets should be pressed together, if the initial temperature of the sheets (and the adhesive) is 30^{o}C. For plastic sheets, thermal conductivity K = 0.25 W/m-K, specific heat C = 2000J/kg-K and density, ρ= 1300 kg/m3.	(7)
10	Consider a two-dimensional plate of thickness 1 cm and size 0.3 m X 0.4 m. The thermal conductivity of the plate material is K = 1000 W/m.K. Two adjacent boundaries of the plate are insulated. Of the remaining two boundaries, the boundary of 0.4 m in length receives a steady heat flux of 500 kW/m^2, and the 0.3 m boundary is maintained at a temperature of 100°C. Use a uniform grid with Δx = Δy = 0.1 m to calculate the steady state temperature distribution inside the plate. Provide the computational grid and algorithm to solve the problem.	(7)
11	A property φ is transported by means of convection and diffusion through the one-dimensional domain $0 \le X \le L$. The governing equation is $\frac{d}{dx}\rho u\varphi = \frac{d}{dx}\left(\Gamma\left(\frac{d\varphi}{dx}\right)\right)$; the boundary conditions are φ_0 = 1 at x = 0 and φ_L = 0 at $x = L$. Using five equally spaced cells and the central differencing scheme for convection and diffusion, calculate the distribution of φ as a function of x for u = 0.1m/s. Compare the results with the analytical solution $(\varphi - \varphi_0)(\varphi_L - \varphi_0) = \frac{\left(e^{\left(\frac{\rho u x}{\Gamma}\right)} - 1\right)}{\left(e^{\left(\frac{\rho u L}{\Gamma}\right)} - 1\right)}$.	(7)
12	Derive the stream function - vorticity formulation for the 2D Navier-Stokes equation by clearly stating the assumptions. Formulate a numerical model for the formulation by appropriately selecting the difference schemes.	(7)

221RGE100	RESEARCH METHODOLOGY AND IPR	Category	L-T-P-C	YOI
			2-0-0-2	2022

Preamble: This course introduces the strategies and methods related to scientific research. The students are also trained in the oral presentation with visual aids and writing technical thesis/reports/research papers. The salient aspects of publication and patenting along with the crucial role of ethics in research is discussed.

Course Prerequisites: Nil

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

CO 1	Approach research projects with enthusiasm and creativity.
CO 2	Conduct literature survey and define research problem
CO 3	Adopt suitable methodologies for solution of the problem
CO 4	Deliver well-structured technical presentations and write technical reports.
CO 5	Publish/Patent research outcome.

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	3				3	
CO 2	3	3				3	
CO 3	3	3				3	
CO 4	3	3				3	
CO 5	3	3				3	

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Apply	70%	**100**	**40**	**60**	**2.5** hours
Analyse	30%				
Evaluate	--				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Course based task

Some sample course-based tasks that can be performed by the student given below. :15 marks

- *Conduct a group discussion based on the good practices in research.*
- *Conduct literature survey on a suitable research topic and prepare a report based on this.*

Seminar :15 marks

Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.) :10 marks

End Semester Examination Pattern: 60 marks

The examination will be conducted by the respective college with the question provided by the University. The examination will be for 150 minutes and contain two parts; Part A and Part B. Part A will contain 6 short answer questions with 1 question each from modules 1 to 4, and 2 questions from module 5. Each question carries 5 marks. Part B will contain only 1 question based on a research article from the respective discipline and carries 30 marks. The students are to answer the questions based on that research article. Sample question for part B is given below:

Part B		
7	Read the given article and write a report that addresses the following issues (The article given can be specific to the discipline concerned)	Marks
	(a) What is the main research problem addressed?	(4)

	(b) Identify the type of research	(4)
	(c) Discuss the short comings in literature review if any?	(4)
	(d) Discuss the significance of the study	(6)
	(e) Discuss appropriateness of the methodology used for the study	(6)
	(f) Summarize the important results and contributions by the authors	(6)

SYLLABUS AND COURSE PLAN		
No.	**Topic**	**No. of Lectures**
1	**Introduction**	
1.1	Meaning and significance of research, Skills, habits and attitudes for research, Types of research,	1
1.2	Characteristics of good research, Research process	1
1.3	Motivation for research: Motivational talks on research: "You and Your Research"- Richard Hamming	1
1.4	Thinking skills: Levels and styles of thinking, common-sense and scientific thinking, examples, logical thinking, division into sub-problems, verbalization, awareness of scale.	1
1.5	Creativity: Some definitions, illustrations from day to day life, intelligence versus creativity, creative process, requirements for creativity	1
2	**Literature survey Problem definition**	
2.1	Information gathering – reading, searching and documentation; types of literature. Journal index and impact factor.	1
2.2	Integration of research literature and identification of research gaps	1
2.3	Attributes and sources of research problems; problem formulation, Research question, multiple approaches to a problem	1
2.4	Problem solving strategies – reformulation or of rephrasing, techniques of representation, Importance graphical representation; examples.	1
2.5	Analytical and analogical reasoning, examples; Creative problem solving using Triz, Prescriptions for developing creativity and problem solving.	1
3	**Experimental and modelling skills**	
3.1	Scientific method; role of hypothesis in experiment; units and dimensions; dependent and independent variables; control in experiment	1
3.2	precision and accuracy; need for precision; definition, detection, estimation and reduction of random errors; statistical treatment of data; definition, detection and elimination of systematic errors;	1
3.3	Design of experiments; experimental logic; documentation	1
3.4	Types of models; stages in modelling; curve fitting; the role of approximations; problem representation; logical reasoning; mathematical skills;	1
3.5	Continuum/meso/micro scale approaches for numerical simulation; Two case studies illustrating experimental and modelling skills.	1
4	**Effective communication - oral and written**	
4.1	Examples illustrating the importance of effective communication; stages and dimensions of a communication process.	1
4.2	Oral communication –verbal and non-verbal, casual, formal and	1

	informal communication; interactive communication; listening; form, content and delivery; various contexts for speaking-conference, seminar etc.	
4.3	Guidelines for preparation of good presentation slides.	1
4.4	Written communication - form, content and language; layout, typography and illustrations; nomenclature, reference and citation styles, contexts for writing – paper, thesis, reports etc. Tools for document preparation-LaTeX.	1
4.5	Common errors in typing and documentation	1
5	**Publication and Patents**	
5.1	Relative importance of various forms of publication; Choice of journal and reviewing process, Stages in the realization of a paper.	1
5.2	Research metrics-Journal level, Article level and Author level, Plagiarism and research ethics	1
5.3	Introduction to IPR, Concepts of IPR, Types of IPR	1
5.4	Common rules of IPR practices, Types and Features of IPR Agreement, Trademark	1
5.5	Patents- Concept, Objectives and benefits, features, Patent process – steps and procedures	2

References:

1. E. M. Phillips and D. S. Pugh, "How to get a PhD - a handbook for PhD students and their supervisors", Viva books Pvt Ltd.
2. G. L. Squires, "Practical physics", Cambridge University Press
3. Antony Wilson, Jane Gregory, Steve Miller, Shirley Earl, Handbook of Science Communication, Overseas Press India Pvt Ltd, New Delhi, 1st edition 2005
4. C. R. Kothari, Research Methodology, New Age International, 2004
5. Panneerselvam, Research Methodology, Prentice Hall of India, New Delhi, 2012.
6. Leedy P. D., Practical Research: Planning and Design, McMillan Publishing Co.
7. Day R. A., How to Write and Publish a Scientific Paper, Cambridge University Press, 1989.
8. William Strunk Jr., Elements of Style, Fingerprint Publishing, 2020
9. Peter Medawar, 'Advice to Young Scientist', Alfred P. Sloan Foundation Series, 1979.
10. E. O. Wilson, Letters to a Young Scientist, Liveright, 2014.
11. R. Hamming, You and Your Research, 1986 Talk at Bell Labs.

221LEE006	EV MODELING AND SIMULATION LAB	Category	L-T-P-C	YOI
		Laboratory	0-0-2-1	2022

Preamble: This course imparts practical knowledge to students through the simulation and modelling of electric vehicles and their various components.

Course Prerequisites: Fundamental knowledge in MATLAB/Simulink, Ansys, Solid Works, CATIA and Autodesk Inventor.

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

CO 1	Conduct a real-time investigation into the performance analysis of electric vehicles, taking into account the different forces acting upon them.
CO 2	Develop the skill to design the suitable power train for electric vehicle
CO 3	Develop a simulation model to design and analyze the performance of power converters in electric vehicle applications.
CO 4	Investigate the performances of series parallel hybrid electric vehicle along with regenerative braking by assessing the various parameters of EV.

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2		2		2	
CO 2	3	2		2		2	
CO 3	3	2		2		2	
CO 4	3	2		2		2	

Assessment Pattern

The laboratory courses will be having only Continuous Internal Evaluation and carries 100 marks.

Mark distribution				Continuous Internal Evaluation Pattern: 100 marks	
Total Marks	**CIE**	**ESE**	**ESE Duration**		
100	**100**	--	--	Regular performance evaluation in the laboratory (Output and record)	**40%**
				Regular Class Viva-Voce:	**20%**
				Final Assessment:	**40%**

Final assessment will be done by two examiners; one examiner will be a senior faculty from the same department assigned by the HOD.

Final Assessment Mark Split up will be as follows:

Preliminary work -30%
Performance – 30%
Results – 20%
Viva-20%

SYLLABUS: LIST OF EXPERIMENTS

A. MANDATORY EXPERIMENT/PROJECT

1. Mathematical modelling and simulation of Electric Vehicle to analyse the effect of Rolling Resistance, Vehicle mass, Aerodynamic drag and Hill Climbing force on vehicle range and Performance using standard software tools.
2. Solid modelling of vehicle parts/Assembly

B. SOFTWARE/SIMULATION EXPERIMENTS (MINIMUM FIVE EXPERIMENTS)

1. Simulation study and analyze the performance of speed control of Induction motor PMSM and BLDC motor drives in EV.
2. Develop a simulation model to analyze Electric Motor Regenerative Braking Characteristics for different Driving Cycles.
3. Simulation study of Battery Management System in EV
4. Develop a simulation model for Series/parallel HEV to analyze the effect of changing of parameters on vehicle range and performance.
5. Design a PID controller for a given system (any type of power converter).
6. Vehicle Surface Modelling of body parts
7. Model and harmonic analysis of vehicle parts/ Assembly

In addition to the above, the department can offer a few newly developed experiments which will be treated as beyond syllabus. Digital control platforms such as DSP/ FPGA/ Microcontrollers/ HIL etc. may be used. Suitable simulation tools may be used for simulation studies. Use of opensource tools such as Python, SciLab, etc. are encouraged.

References:

1. Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design" by Mehrdad Ehsani, Yimin Gao, and Ali Emadi
2. Engineering Design with SolidWorks" by David Planchard
3. Permanent Magnet Synchronous and Brushless DC Motor Drives" by R. Krishnan
4. Regenerative Braking Systems for Electric Vehicles" by Chris Mi and Andrew Emadi
5. Mechanical Vibrations: Theory and Applications" by S. Graham Kelly

SEMESTER II

SLOT	COURSE CODE	COURSE NAME	MARKS		L-T-P	Hrs.	CREDIT
			CIA	ESE			
A	222TEE008	BATTERY MANAGEMENT SYSTEMS FOR EVs	40	60	3-0-0	3	3
B	222TEE009	VEHICLE DYNAMICS AND CONTROL	40	60	3-0-0	3	3
C	222EXXXXX	PROGRAM ELECTIVE 3	40	60	3-0-0	3	3
D	222EXXXXX	PROGRAM ELECTIVE 4	40	60	3-0-0	3	3
E	222EEXXXX/ 222EEEXXX	INDUSTRY/ INTERDISCIPLINARY ELECTIVE	40	60	3-0-0	3	3
S	222PEE100	MINI PROJECT	100	--	0-0-4	4	2
T	222LEE006	EV HARDWARE LAB	100	--	0-0-2	2	1
		Total	**400**	**300**		**21**	**18**

Teaching Assistance: 6 hours

PROGRAM ELECTIVE 3						
SLOT	SL NO	COURSE CODE	COURSE NAME	L-T-P	Hrs.	CREDIT
C	1	222EEE037	SPECIAL ELECTRICAL MACHINES AND DRIVES	3-0-0	3	3
	2	222EEE046	ELECTRIC VEHICLE ENGINEERING AND DEVELOPMENT	3-0-0	3	3
	3	222EEE012	EMBEDDED PROCESSORS AND CONTROLLERS	3-0-0	3	3

PROGRAM ELECTIVE 4						
SLOT	SL NO	COURSE CODE	COURSE NAME	L-T-P	Hrs.	CREDIT
D	1	222EEE008	DESIGN OF POWER ELECTRONIC SYSTEM	3-0-0	3	3
	2	222EEE020	HYDROGEN AND FUEL CELL TECHNOLOGIES	3-0-0	3	3
	3	222EEE022	EV CHARGING SYSTEMS	3-0-0	3	3

INTERDISCIPLINARY/ INDUSTRY ELECTIVE						
SLOT	SL NO	COURSE CODE	COURSE NAME	L-T-P	Hrs.	CREDIT
E	1	222EEE056	ELECTRIC AND HYBRID VEHICLES	3-0-0	3	3
	2	222EEE071	ELECTRIC CHARGING SYSTEMS FOR ELECTRICAL VEHICLES	3-0-0	3	3

222TEE008	BATTERY MANAGEMENT SYSTEMS FOR EVs	Category	L-T-P-C	YOI
		Program Core 3	3-0-0-3	2022

Preamble: This course intends to provide in-depth knowledge on various batteries, ageing and battery management system used in EVs. This course gives an insight into on-board and off- board charger and charger standards. This course also introduces various fuel cell technologies.

Course Prerequisites: Nil

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

CO 1	Select appropriate batteries for electric vehicles (EVs)
CO 2	Design battery pack for EVs
CO 3	Apply the concepts of battery management system for onboard and offboard chargers
CO 4	Explain aging and repurposing of battery pack used in EVs
CO 5	Discuss suitable fuel cells used in EVs and explore various control strategies for hybrid energy storage based HEV

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3						
CO 2	3	3	3	2		2	
CO 3	3	3	3	2	2	2	
CO 4	3					2	
CO 5	3	3	2	2	2	2	

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Understand	20%	100	40	60	2.5 hours
Apply	60%				
Analyse	20%				
Evaluate	--				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Micro project/Course based project (The project shall be done individually. Group projects not permitted.) :20 marks
Course based task/Seminar/Quiz :10 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.) :10 marks

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions, with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions, with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks.

SYLLABUS

MODULE I (8 Hours)

Types of battery for electric vehicles: Introduction; Battery Parameters - Cell and battery voltages, Charge (or AH) capacity, Energy stored, Energy density, Specific power, AH (or charge) efficiency, Energy efficiency, Self-discharge rates, Battery geometry, Battery temperature; Heating and cooling needs; Battery life and number of deep cycles.

Nickel–metal hydride (Ni-MH) and nickel–zinc batteries (Ni-Zn) for EVs - Technical description of Ni-MH and Ni-Zn batteries - Electrical performance, lifetime.

Cost of Ni-MH and Ni-Zn batteries - Comparison of Ni-MH and Ni-Zn batteries in EVs; Design issues - applications - environmental and safety aspects.

Lithium-ion batteries for EVs-cell design-pack design- environmental and safety aspects; Lithium- Sulphur battery- Lithium-air battery.

MODULE II (8 Hours)

Battery pack design: Components of HV battery packs - Requirements of HV battery packs; High-voltage battery management systems (BMS) for electric vehicles - Requirements for HV.

BMS - Topology of BMS; Design of HV BMS - Cell balancing, battery state estimation. Safety aspects of battery management systems for electric vehicles.

Thermal management of batteries for electric vehicles- Motivation for battery thermal management; Heat sources sinks, and thermal balance - Design aspects of thermal management Systems

MODULE III (9 Hours)

BMS for onboard and offboard chargers: Voltage cell battery equalization - resistive, inductive, capacitive equalisers; Cuk equalisers - transformer based equalisers- importance of battery cell equalization; Charging architectures for Electric and Plug-In Hybrid Electric Vehicles – different configurations - onboard chargers; Dedicated converter - integrated converter; Off board chargers- Dedicated Off-Board DC Chargers - Challenges for Fast Charging Stations - EV / PHEV charging Standards.

MODULE IV (7 Hours)

Aging and repurposing: Aging effects - Aging mechanisms and root causes; Aging of battery packs - Testing - Diagnostic methods; Extension of battery lifetime; Repurposing of batteries from electric vehicles - problem being addressed - Advantages of battery repurposing; Computer simulation for battery design and lifetime - introduction - essentials of modeling approach.

MODULE V (8 Hours)

Application of fuel cells in EVs and HEVs: Operation principles of fuel cell - characteristics;

Fuel cell technologies - Proton Exchange Membrane Fuel Cells - Alkaline Fuel Cells; Phosphoric Acid Fuel Cells - Molten Carbonate Fuel Cells- Solid Oxide Fuel Cells-Direct Methanol Fuel; Fuel supply - hydrogen production and storage-non hydrogen fuel cells; Fuel cell hybrid electric drive train design - configuration - control strategy-parametric design; Fuel cell – battery based hybrid energy storage system – control strategies

Text book:

1. C.C Chan, K.T Chau: Modern Electric Vehicle Technology, Oxford University Press Inc., New York 2001.
2. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003.
3. Gregory L. Plett, Battery Management Systems vol-1, vol-2 ISBN-13: 978-1-63081-023-8, ISBN-13: 978-1-63081-027-6
4. Selected Articles Published by MDPI, Emerging Technologies for Electric and Hybrid Vehicles, ISBN 978-3-03897-191-7 (PDF)
5. Sheldon S. Williamson, Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles, Springer, ISBN 978-1-4614-7711-2

References:

1 Bruno Scrosati, Jürgen Garcheand Werner Tillmetz, Advances in Battery Technologies

	for Electric Vehicles ISBN 978-1-78242-398-0
2	Mehrdad Ehsani,Yimin Gao,Stefano Longo,Kambiz M. Ebrahimi Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, CRC press,3 rd-Edition, ISBN: 978-1-4987-6177-2 (Hardback)
3.	James Larminie Oxford Brookes University, Oxford, UK John Lowry Acenti Designs Ltd., UK, Electric Vehicle Technology Explained.
4.	Hilda Bridges, Hybrid Vehicles and Hybrid Electric Vehicles New Developments, Energy Management and Emerging Technologies, Nova Science Publishers, Inc.
5.	Ottorino Veneri, Technologies and Applications for Smart Charging of Electric and Plug-in Hybrid Vehicles, springer, ISBN 978-3-319-43651-7

COURSE PLAN		
No.	**Topic**	**No. of Lectures**
1	**MODULE I (6 hours)**	
1.1	Types of battery for electric vehicles: Introduction; Battery Parameters - Cell and battery voltages, Charge (or AH) capacity, Energy stored, Energy density, Specific power, AH (or charge) efficiency, Energy efficiency, Self- discharge rates, Battery geometry, Battery temperature; Heating and cooling needs; Battery life and number of deep cycles.	2
1.2	Nickel–metal hydride (Ni-MH) and nickel–zinc batteries (Ni-Zn) for EVs - Technical description of Ni-MH and Ni-Zn batteries - Electrical performance, lifetime.	2
1.3	Cost of Ni-MH and Ni-Zn batteries - Comparison of Ni-MH and Ni-Zn batteries in EVs; Design issues - applications - environmental and safety aspects.	2
1.4	Lithium-ion batteries for EVs-cell design-pack design-environmental and safety aspects; Lithium-sulphur battery-Lithium-air battery.	2
2	**MODULE II (8 hours)**	
2.1	Battery pack design: Components of HV battery packs - High-voltage battery management systems (BMS) for electric vehicles - Requirements of HV battery packs	1
2.2	BMS - Topology of BMS; Design of HV BMS - Cell balancing, battery state estimation, Safety aspects of battery management systems for electric vehicles.	4
2.3	Thermal management of batteries for electric vehicles- Motivation for battery thermal management; Heat sources sinks, and thermal balance - Design aspects of thermal management Systems	3
3	**MODULE III (9 hours)**	
3.1	BMS for onboard and offboard chargers: Voltage cell battery equalization - resistive, inductive, capacitive equalisers; Cuk equalisers - transformer based equalisers- importance of battery cell equalization.	3
3.2	Charging architectures for Electric and Plug-In Hybrid Electric Vehicles – different configurations - onboard chargers; Dedicated converter - integrated converter.	3
3.3	Off board chargers- Dedicated Off-Board DC Chargers - Challenges for Fast Charging Stations.	2
3.4	EV / PHEV charging Standards.	1
4	**MODULE IV (7 hours)**	
4.1	Aging and repurposing: Aging effects - Aging mechanisms and root causes; Aging of battery packs - Testing - Diagnostic methods;	3

4.2	Extension of battery lifetime; Repurposing of batteries from electric vehicles - problem being addressed - Advantages of battery repurposing	2
4.3	Computer simulation for battery design and lifetime - introduction - essentials of Modeling approach.	2
5	**MODULE V (8 hours)**	
5.1	Application of fuel cells in EVs and HEVs: Operation principles of fuel cell - characteristics;	1
5.2	Fuel cell technologies - Proton Exchange Membrane Fuel Cells - Alkaline Fuel Cells; Phosphoric Acid Fuel Cells - Molten Carbonate Fuel Cells- Solid Oxide Fuel Cells-Direct Methanol Fuel;	3
5.3	Fuel supply - hydrogen production and storage-non hydrogen fuel cells; Fuel cell hybrid electric drive train design - configuration - control strategy- parametric design;	2
5.4	Fuel cell – battery-based hybrid energy storage system – control strategies	2

MODEL QUESTION PAPER

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

222TEE008 BATTERY MANAGEMENT SYSTEMS FOR EVs

Max. Marks: 60 **Time: 2.5 Hrs.**

Sl.	**Part A** **(Answer all questions)**	**Marks**
1	Define the terms energy density, specific power and Ah efficiency of batteries.	(5)
2	Explain the need of thermal management in EV Battery packs.	(5)
3	Explain the charging architecture of plug-in hybrid electric vehicles.	(5)
4	Explain the effect of SoC and SoC variation on cell aging.	(5)
5	Explain fuel cell- battery based hybrid energy storage system with a neat diagram.	(5)
	Part B **(Answer any five questions)**	
6	Explain the construction and working of Lithium Sulphur battery.	(7)
7	Describe various cell balancing techniques with equations.	(7)
8	Explain the working of off-board charger with necessary diagrams.	(7)
9	Describe various methods of voltage cell battery equalization.	(7)
10	Elaborate on the root causes, mechanisms and diagnostic methods of ageing in batteries.	(7)
11	With neat diagram explain construction and working of proton exchange membrane fuel cell.	(7)
12	With neat diagram explain construction and working of direct methanol fuel cell.	(7)

222TEE009	VEHICLE DYNAMICS & CONTROL	Category	L-T-P-C	YOI
		Program Core 4	3-0-0-3	2022

Preamble: A clear understanding of Vehicle Dynamics is needed to predict any vehicle's behavior under different conditions. Also, a control engineer needs models that are both simple enough to use for control system design and rich enough to capture all the essential features of the dynamics. This course aims to provide important concepts of road vehicle dynamics and control. The modeling approaches and characteristics of the vehicle and tire model for handling and driving dynamics are introduced in the program.

Course Prerequisites: Nil

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

CO 1	Use fundamental equations to model the physical systems.
CO 2	Use the dynamics of wheel and tire in the analysis of road vehicle.
CO 3	Analyse longitudinal dynamic response of road vehicle during acceleration and braking.
CO 4	Analyse lateral dynamic response of road vehicle during cornering.
CO 5	Analyse ride, pitch, and roll performance of road vehicle using vertical dynamic response.

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3		2	3		2	
CO 2	3		2	3		2	
CO 3	3		3	3		3	
CO 4	3		3	3		3	
CO 5	3		3	3		3	

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Apply	70%	100	40	60	2.5 hours
Analyse	20%				
Evaluate	10%				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Micro project/Course based project
(The project shall be done individually. Group projects not permitted.) :20 marks
Course based task/Seminar/Quiz :10 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.) :10 marks

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions, with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions, with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks.

SYLLABUS
MODULE I
INTRODUCTION: Dynamic systems: Linearity, Time Invariance, Causality, Models as Ordinary differential equations, Transfer Function Representation, State space representation, Stability, Transient response- First and second order systems Kinematics: Translation, Rotation, Composition of rotations, Rotation about an arbitrary axis, Velocity analysis, Acceleration analysis. Dynamics: Linear momentum, Angular momentum, Moment of Inertia, Newton-Euler Formulation, Euler- Lagrange Formulation
MODULE II
TIRE: Tire Mechanics – An Introduction Mechanical Properties of Rubber - Slip, Grip and Rolling Resistance - Tire Construction and Force Development - Contact Patch and Contact Pressure Distribution. A Simple Tire Model-Lateral Force Generation - Ply Steer and Conicity - Tire Models – Pacejka's Magic formula - Classification of Tire Models and Combined Slip
MODULE III
LATERAL DYNAMICS: Steering geometry, trapezoidal steering mechanism. Kinematic steering model. Dynamic steering model- Understeer gradient, concepts of understeer and over steer, cornering stability. Handling characteristics, evaluation of cornering performance-Mimuro plot.
MODULE IV
LONGITUDINAL VEHICLE DYNAMICS: Longitudinal Vehicle Dynamics, Aerodynamic drag force, Longitudinal tire force, Rolling resistance, Calculation of normal tire forces, Calculation of effective tire radius. Acceleration-powertrain model, drive force calculations, transmission matching. Braking- braking model, brake force distribution, stopping distance, Antilock brake system
MODULE V
VERTICAL DYNAMICS: Quarter car model- ride comfort, road holding. Half car model-roll, pitch. State space and transfer function representations
Text book: 1. J. Wong, Theory of Ground Vehicles. 2. R. Rajamani, Vehicle Dynamics, and Control. 3. R. N. Jazar, Vehicle Dynamics: Theory and Application.
References: 1. G. Rill, Road Vehicle Dynamics: Fundamentals and Modeling. *2.* 5. T. Gillespie, Fundamentals of Vehicle Dynamics.

Course Plan (For 3 credit courses, the content can be for 40 hrs and for 2 credit courses, the content can be for 26 hrs. The audit course in third semester can have content for 30 hours).

COURSE PLAN		
No.	**Topic**	**No. of Lectures**
1	**MODULE I: Dynamic systems (8 hours)**	
1.1	Linearity, Time Invariance, Causality, Models as Ordinary differential equations	2
1.2	Transfer Function Representation, State space representation, Stability, Transient response- First and second order systems	2
1.3	Kinematics: Translation, Rotation, Composition of rotations, Rotation about an arbitrary axis, Velocity analysis, Acceleration analysis.	2
1.4	Dynamics: Linear momentum, Angular momentum, Moment of Inertia, Newton-Euler Formulation, Euler- Lagrange Formulation	2
2	**MODULE II: TIRE (8 Hours)**	

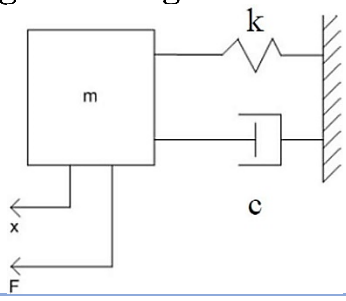
2.1	Tire Mechanics – An Introduction Mechanical Properties of Rubber - Slip, Grip and Rolling Resistance	1
2.2	Tire Construction and Force Development - Contact Patch and Contact Pressure Distribution.	2
2.3	A Simple Tire Model Lateral Force Generation - Ply Steer and Conicity	2
2.4	Tire Models – Pacejka's Magic formula - Classification of Tire Models and Combined Slip	2
3	**MODULE III: LATERAL DYNAMICS (8 hours)**	
3.1	Steering geometry, trapezoidal steering mechanism.	2
3.2	Kinematic steering model.	2
3.3	Dynamic steering model- Understeer gradient, concepts of understeer and over steer, cornering stability.	2
3.4	Handling characteristics, evaluation of cornering performance- Mimuro plot.	2
4	**MODULE IV: LONGITUDINAL VEHICLE DYNAMICS (8 hours)**	
4.1	Longitudinal Vehicle Dynamics, Aerodynamic drag force, Longitudinal tire force, Rolling resistance	2
4.2	Calculation of normal tire forces, Calculation of effective tire radius.	2
4.3	Acceleration-powertrain model, drive force calculations, transmission matching.	2
4.4	Braking- braking model, brake force distribution, stopping distance, Antilock brake system.	2
5	**MODULE V: VERTICAL DYNAMICS (8 hours)**	
5.1	Quarter car model- ride comfort, road holding. Transfer function representations	2
5.2	Quarter car model- ride comfort, road holding. State space representations	2
5.3	Half car model- roll, pitch. State space representations	2
5.4	Half car model- roll, pitch. Transfer function representations	2

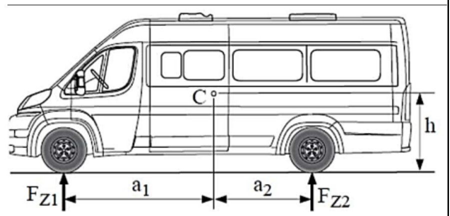
MODEL QUESTION PAPER

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

222TEE009 VEHICLE DYNAMICS AND CONTROL

Max. Marks: 60 **Time: 2.5 Hrs.**

Sl.	**Part A** **(Answer all questions)**	**Marks**
1	Derive the transfer function and state space model of spring mass damper system given in Figure. 	(5)
2	Find the height, diameter, and radius of given tire P235/75R15 based on tire numbers. The aspect ratio is given as 75 %.	(5)
3	Consider a vehicle having a mass of 1000 kg travelling at an initial speed of (V1) of 80 km/h. Let the driver reaction time (t_d) be 1 s, the brake response time (t_b) be 0.25 s and the deceleration	(5)

<table>
<tr><td></td><td>rise time (t_r) be 0.3 s. Obtain the expression for the stopping distance. Determine the stopping distance of the vehicle if the final constant deceleration of the vehicle is 6 m/s^2.</td><td></td></tr>
<tr><td>4</td><td>Obtain the governing equations of kinematic model. Also derive the expression for side slip angle.</td><td>(5)</td></tr>
<tr><td>5</td><td>Derive the rattle space transfer function and tire deflection transfer function of a quarter car model</td><td>(5)</td></tr>
<tr><td></td><td>Part B
(Answer any five questions)</td><td></td></tr>
<tr><td>6</td><td>Write the governing equations for the inverted pendulum. Are the resulting equations linear or nonlinear? If nonlinear, Obtain the corresponding linearized equations. Also express the model in state space representations.</td><td>(7)</td></tr>
<tr><td>7</td><td>A tire with an unloaded radius of r_0 = 0:546 m is exposed to a vertical force of F_z = 35 kN. Calculate the vertical tire stiffness c_z and the contact length L if a loaded or static tire radius of r_S = 0:510 m is measured.</td><td>(7)</td></tr>
<tr><td>8</td><td>Derive the bicycle model in terms of yaw rate and side slip angle for lateral vehicle motion.</td><td>(7)</td></tr>
<tr><td>9</td><td>A minibus with a wheelbase of a = a_1 +a_2 = 4 m is characterized by the following parameters:
<table>
<tr><td></td><td>unladen</td><td>laden</td><td rowspan="4">
</td></tr>
<tr><td>Axle load front</td><td>F_{Z1}=15 kN</td><td>F_{Z1}=20 kN</td></tr>
<tr><td>Axle load rear</td><td>F_{Z2}=14 kN</td><td>F_{Z2}=23 kN</td></tr>
<tr><td>COG height</td><td>h=1.2 m</td><td>h=1.4 m</td></tr>
</table>
Determine the mass of the vehicle and the horizontal position of the center of gravity (COG) defined by the parameters a1 and a2 for the unladen and laden vehicle. The wheels have radius R = 0.372 m and now the vehicle is supposed to decelerate with $\dot{v}/g = -0.6$
Calculate the required braking torques at the front and rear axle when an optimal distribution is taken for granted.</td><td>(7)</td></tr>
<tr><td>10</td><td>Consider a road vehicle weighing 20 kN and a wheelbase of 2.8 m. The front-rear static weight distribution is 55 %-45%. If the cornering stiffness of each of the four tyres is 40 kN/rad, comment on the steady state handling response of the vehicle.</td><td>(7)</td></tr>
<tr><td>11</td><td>Consider a two-degree freedom dynamic model for lateral dynamics. How can this model be used for handling evaluation? What parameters can be extracted from test data would characterize handling response?</td><td>(7)</td></tr>
<tr><td>12</td><td>Derive the state space representations of quarter car mode with state variables as suspension deflection, sprung mass velocity, tyre deflection, and unsprung mass velocity.</td><td>(7)</td></tr>
</table>

222EEE037	SPECIAL ELECTRICAL MACHINES AND DRIVES	Category	L-T-P-C	YOI
		Program Elective-3	3-0-0-3	2022

Preamble: This course provides an insight into special electrical machines & drives and equips the students capable of selecting suitable drives for industrial applications.

Course Prerequisites: Nil

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

CO 1	Apply the knowledge of stepper motor drives for industrial applications
CO 2	Apply the knowledge of switched reluctance motor drives for industrial applications
CO 3	Apply the knowledge of permanent magnet brushless and synchronous motor drives for industrial applications.
CO 4	Apply the knowledge of magnet less motor drives for industrial applications
CO 5	Select motor drive technologies for EVs

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	3	3	2	2	
CO 2	3	2	3	3	2	2	
CO 3	3	2	3	3	2	2	
CO 4	3	2	3	3	2	2	
CO 5	3	2	3	3		2	

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Apply	40%	100	40	60	2.5 hours
Analyse	40%				
Evaluate	20%				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred)	:15 marks
Course based task/Seminar/Data collection and interpretation	:15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.)	:10 marks

End Semester Examination Pattern: 60 marks

Part A: 5 numerical/short answer questions with 1 question from each module, (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.
Each question can carry 5 marks.
Part B: 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five.
Each question can carry 7 marks.
Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example, if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

SYLLABUS
MODULE I (7 Hrs)
Stepper Motors and Drives: Types -Variable reluctance, permanent magnet and hybrid motors - Constructional features - principle of operation - modes of excitation. Torque production in variable reluctance stepping motor: Static torque characteristics - position error due to low torque; Performance parameters - resolution - single step response and accuracy; Pull-in and pull-out characteristics – Resonance issues. Unipolar and bipolar drive schemes – Bifilar drives – Open loop position control - starting/stopping rate – Velocity profiling *Assignment: Closed loop control of stepper motors*
MODULE II (10 Hrs)
Permanent Magnet Synchronous Motor (PMSM) Drives: Permanent magnet materials and characteristics, PMSM – Principle of operation, SPM and IPM machines, Torque equation, Phasor diagram, Machine modeling, switching schemes, Motor control - Field oriented control, Flux weakening, Sensor less control, Power controllers. Brushless DC Motor (BLDC) Drives: BLDC motors- constructional details – principle of operation; Speed-Torque characteristics -Torque Pulsation, Machine modeling. Switching schemes for BLDC operation, Motor control - Power controllers – full wave and half wave converters – regeneration – Hall sensor-based control, Phase advance angle control, Sensor less control.
MODULE III (10 Hrs)
Switched Reluctance Motors (SRM) and Drives: SRM – Principle of operation, Inductance profile, torque equation, Motoring and regeneration. Low speed and high-speed operation – Characteristics, Energy conversion loop - Energy effectiveness. Power controllers, Control schemes – Six switch converter – Split DC supply converter – R dump, C dump converters. Soft switching converter topologies, Torque ripple minimization.
MODULE IV (8 Hrs)
Advanced Magnetless Motor Drives: Synchronous reluctance motors, Permanent magnet synchronous reluctance motors –- Constructional details, Principle of operation, Different topologies, Vernier reluctance motors, Applications. Field oriented control principles, Direct torque and flux control. Vernier permanent magnet motors: Constructional details, Principle of operation, Modelling. Inverters for Vernier PM motors, Vernier PM Motor control, Applications.
MODULE V (5 Hrs)
Motor Drive Technologies for EVs: Classification of motors for EV drives, performance requirements, drive cycles – IDC, MIDC, WLTP. EV propulsion systems, Vehicle traction power plant, Ideal torque speed characteristics. Motors for EV Drives, Challenges in machine design: oscillations and vibrations, Torque ripple, Audible noise. Standards, Materials used - PM materials. Regenerative braking, ABS braking using motor drive including optimum regeneration.
Text book: [1] K T Chau, “Electric Vehicle Machines and Drives – Design, Analysis and Application”, John Wiley & Sons Singapore Pte. Ltd., 2015. [2] Mehrdad Ehsani, YiminGao, Sebastien E. Gay & Ali Emadi, “Modern Electric, Hybrid Electric and Fuel Cell Vehicles - Fundamentals, Theory and Design” , CRC Press, 2005. [3] Ion Boldea, Lucian Tutelea, “Reluctance Electric Machines-Design and Control”, CRC Press, 2019
References: [1] R Krishnan, “Electric Motor Drives – Modeling, Analysis and Control”, Pearson Education Ltd., 2015.

[2] R. Krishnan, “Switched Reluctance Motor Drives–Modeling, Simulation, Analysis, Design and Applications”, CRC Press, 2001.
[3] R Krishnan, “Permanent Magnet Synchronous and brushless dc drives”, CRC Press, 2010.
[4] D. C. Hanselman, “Brushless Permanent Magnet Motor Design”, Magna Physics Pub, 2006.
[5] Ali Emadi, “Handbook of Automotive Power Electronics and Motor Drives”, Taylor & Francis, 2005.
[6] Ned Mohan, “Advanced Electric Drives”, John Wiley & Sons Inc., 2014.
[7] B K Bose, “Modern Power Electronics & AC drives”, Pearson Education Ltd., 2002.
[8] T.J.E.Miller, “Brushless Permanent Magnet and Reluctance Motor Drives”, Clarendon Press, Oxford, 1989.
[9] T J E Miller, “Switched reluctance motors and their control”, Oxford University Press, 1993.
[10] Ion Boldea, “Linear Electric Machines, Drives and MAGLEVs Handbook”, CRC Press, 2013.
[11] Kenjo T, Sugawara A, “Stepping Motors and their Microprocessor Control”, Clarendon Press, Oxford, 1994.
[12] Paul Acarnley, “Stepping motors - a guide to theory and practice”, 4th Edition. IET UK, 2002.

COURSE PLAN		
No.	**Topic**	**No. of Lectures**
1	**MODULE I (7 hours)**	
1.1	Stepper Motors and Drives: Variable reluctance, permanent magnet and hybrid motors- Principle of operation.	2
1.2	Torque production – Static position error- pull-in and pull-out characteristics – Resonance issues.	2
1.3	Unipolar and Bipolar drive schemes – Bifilar drives – Open loop position control - Starting/stopping rate – Velocity profiling.	3
2	**MODULE II (10 hours)**	
2.1	Permanent Magnet Synchronous Motor (PMSM) Drives: Permanent magnet materials and characteristics, PMSM – Principle of operation, SPM and IPM machines, Torque equation, Phasor diagram, Machine modeling.	2
2.2	Switching schemes, Motor control - Field oriented control, Flux weakening, Sensor less control, Power controllers.	3
2.3	Brushless DC Motor (BLDC) Drives: BLDC motors- constructional details – principle of operation; Speed-Torque characteristics - Torque Pulsation, Machine modeling.	2
2.4	Switching schemes for BLDC operation, Motor control - Power controllers – full wave and half wave converters – regeneration – Hall sensor-based control, Phase advance angle control, Sensor less control.	3
3	**MODULE III (10 hours)**	
3.1	Switched Reluctance Motors (SRM) and Drives: SRM – Principle of operation, Inductance profile, Torque equation, Motoring and regeneration.	3
3.2	Low speed and high-speed operation – Characteristics, Energy conversion loop- Energy effectiveness.	2
3.3	Power controllers, Control schemes – Six switch converter – Split DC supply converter – R dump, C dump converters.	3
3.4	Soft switching converter topologies, Torque ripple minimization.	2

3.5		1
4	**MODULE IV (8 hours)**	
4.1	Advanced Magnetless Motor Drives: Synchronous reluctance motors, Permanent magnet synchronous reluctance motors –- Constructional details, Principle of operation, Different topologies, Vernier reluctance motors, Applications.	3
4.2	Field oriented control principles, Direct torque and flux control.	2
4.3	Vernier permanent magnet motors: Constructional details, Principle of operation, Modelling.	1
4.4	Inverters for Vernier PM motors, Vernier PM Motor control, Applications.	2
5	**MODULE V (5 hours)**	
5.1	Motor Drive Technologies for EVs: Classification of motors for EV drives, performance requirements, drive cycles – IDC, MIDC, WLTP.	1
5.2	EV propulsion systems, Vehicle traction power plant, Ideal torque speed characteristics.	1
5.3	Motors for EV Drives, Challenges in machine design: oscillations and vibrations, Torque ripple, Audible noise. Standards, Materials used - PM materials.	2
5.4	Regenerative braking, ABS braking using motor drive including optimum regeneration.	1

MODEL QUESTION PAPER

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

222EEE037 SPECIAL ELECTRICAL MACHINES AND DRIVES

Max. Marks: 60 **Time: 2.5 Hrs.**

Sl.	**Part A (Answer all questions)**	**Marks**
1	Assuming ideal current waveforms, derive an expression for the pull-out torque of a three-phase stepper motor.	(5)
2	Compare NdFeB, SmCo, Alnico and ceramic magnets for use in permanent magnet machines in terms of magnet stabilization and energy product and draw typical BH curves for the normal quadrant of operation.	(5)
3	Discuss why SRM is usually operated in saturated magnetic conditions rather than the unsaturated magnetic conditions. What is the significance of the term energy effectiveness?	(5)
4	Derive the torque equation of synchronous reluctance motors. Draw the torque speed characteristics.	(5)
5	Summarize the challenges in the design of machines for EV drives.	(5)
	Part B (Answer any five questions)	
6	A three phase, 2 Nm, 0.0005Kgm2 , VR stepping motor has 16 stator teeth and 20 rotor teeth and is used to drive a frictional load of 0.2 Nm (a) Draw the approximate holding torque curve and mark the no load equilibrium points (b) What is the static position error at load? (c) What is the stepping rate corresponding to a speed of 30 RPM? (d) Determine the approximate pull out torque assuming ideal current waveform.	(7)
7	Derive the torque-speed characteristics of a BLDC motor and compare with that of a DC shunt motor. If a PM brushless DC motor has a torque constant of 0.12 N m/A (1) Estimate its no-	(7)

	load speed in rpm when connected to a 48 V DC supply. (2) If the armature resistance is 0.15Ω/phase and the total voltage drop in the controller transistors is 2 V, determine the stall current and the stall torque.	
8	Discuss the principle of operation of hall sensors and illustrate (i) how these sensors are mounted on the motor and (ii) how they are utilized for position detection and switch sequencing in a BLDC motor.	(7)
9	Sketch the L-θ profile of an SRM and point out the constraints on pole arc and tooth arc.	(7)
10	Illustrate with sketches and necessary waveforms, any one type of low-cost drive circuit for an 8/6 SRM during (a) motoring operation and (b) regenerative braking.	(7)
11	Outline the field-oriented control strategy for speed control of synchronous reluctance motors.	(7)
12	Compare the EV driving cycles IDC, MIDC and WLTP.	(7)

222EEE046	Electric Vehicle Engineering and Development	Category	L-T-P-C	YOI
		Program Elective 3	3-0-0-3	2022

Preamble: This course intends to provide an in-depth knowledge of Electric Vehicle Engineering and development process, Electric Vehicle architecture, basic packaging, Introduction to Sensors, electronic control unit (ECU), Electromagnetic interference (EMI) and electromagnetic compatibility (EMC),

Course Prerequisites: Nil

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

CO 1	Explain Electric Vehicle Engineering and development process
CO 2	Describe the electric vehicle architecture and translate to engineering specifications
CO 3	Understand the Product Development process
CO 4	Apply concepts of vehicle attributes and quality function deployment

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2				2	
CO 2	3	2				2	
CO 3	3	2				2	
CO 4	3	2				2	

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Apply	60%	100	40	60	2.5 hours
Analyse	20%				
Evaluate	20%				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred)	:15 marks
Course based task/Seminar/Data collection and interpretation	:15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.)	:10 marks

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions, with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions, with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks.

SYLLABUS

MODULE I (8 hours)

System Engineering, introduction to Electric Vehicle as a system. Hard point Engineering, vehicle integration _Internal Combustion Engine Vehicle (ICEV)), Electric Vehicles, (EV) Fuel Cell Electric Vehicles (FCEV)

MODULE II (8 hours)

Electric Vehicle architecture, basic packaging, and Introduction to Sensors, electronic control unit (ECU), Electromagnetic interference (EMI) and electromagnetic compatibility (EMC), Platforms, Modularity, and Commonality

MODULE III (8 hours)
Vehicle attributes Quality Function Deployment, Key Buying Factors, translating to Vehicle & aggregates, Variant Tree, Product Development (PD) Process Advanced Product Quality Planning (APQP), Lean Development Process
MODULE IV (8 hours)
Design failure mode and effect analysis (DFMEA), Process Failure Mode Effects Analysis (PFMEA), Design Verification and validation Plan (DVVP), Design for Quality, Cost, Manufacturing, assembly, maintenance, service.
MODULE V (8 hours)
Verification, Validation, Testing, Regulatory Requirements, Homologation Process, Supply chain, system partners, concurrent Engineering, Case Studies
Text book: 1. Rand D.A.J, Woods, R & Dell RM Batteries for Electric vehicles, research studies press, UK, 1998. 2. M. Ehsani, Y. Gao and A. Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, 2nd Edition, CRC Press, 2009.
References: 1. J. Larminie and J. Lowry, Electric Vehicle Technology Explained, Second Edition, 2018, Wiley India. 2. J. Jiang and C. Zhang, Fundamentals and Applications of Lithium- Ion Batteries in Electric Drivevehicles, 2015, John Wiley & Sons Singapore Pte. Ltd 3. Iqbal Hussain, Electric & Hybrid Vehicles – Design Fundamentals, CRC Press, 2011

COURSE PLAN		
No.	**Topic**	**No. of Lectures**
1	**MODULE I (8 hours)**	
1.1	System Engineering, introduction to Electric Vehicle as a system.	3
1.2	Vehicle integration _Internal Combustion Engine Vehicle (ICEV)	3
1.3	Electric Vehicles, (EV) Fuel Cell Electric Vehicles (FCEV)	2
2	**MODULE II (8 hours)**	
2.1	Electric Vehicle architecture, basic packaging	2
2.2	Introduction to Sensors	2
2.3	Electronic control unit (ECU), Electromagnetic interference (EMI) and electromagnetic compatibility	2
2.4	Modularity, and Commonality	2
3	**MODULE III (8 hours)**	
3.1	Vehicle attributes Quality Function Deployment	3
3.2	Key Buying Factors, translating to Vehicle & aggregates, Variant Tree, Product Development (PD) Process	3
3.3	Advanced Product Quality Planning (APQP), Lean Development Process	2
4	**MODULE IV (8 hours)**	
4.1	Design failure mode and effect analysis (DFMEA),	3
4.2	Process Failure Mode Effects Analysis (PFMEA)	2
4.3	Design Verification and validation Plan (DVVP)	2
4.4	Design for Quality, Cost, Manufacturing, assembly, maintenance, service.	1
5	**MODULE V (8 hours)**	
5.1	Verification, Validation, Testing, Regulatory Requirements	3
5.2	Homologation Process, Supply chain	3
5.3	System partners, concurrent Engineering, Case Studies	2

MODEL QUESTION PAPER		
SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR		
222EEE046 ELECTRIC VEHICLE ENGINEERING AND DEVELOPMENT		
Max. Marks: 60		Time: 2.5 Hrs.
Sl.	**Part A (Answer all questions)**	**Marks**
1	Explain the steps in vehicle integration of an Internal Combustion Engine Vehicle.	(5)
2	Elaborate various ECUs used in an EV, with its functions.	(5)
3	Describe the Product Development Life Cycle of EV.	(5)
4	Explain various steps involved in the Design Verification and validation Plan of an EV integration.	(5)
5	Describe the Homologation Process of EVs.	(5)
	Part B (Answer any five questions)	
6	Describe the steps in vehicle integration of an Electric Vehicle, with necessary diagrams.	(7)
7	What is meant by EMI and EMC? What are the measures to reduce EMI/EMC issues in an Electric vehicle?	(7)
8	Elaborate the Process Advanced Product Quality Planning (APQP), Lean Development Process of EV.	(7)
9	Describe the procedure of Design failure mode and effect analysis (DFMEA) in EV with necessary diagrams.	(7)
10	Elaborate the procedure of Process Failure Mode Effects Analysis (PFMEA) in EV with necessary diagrams.	(7)
11	Describe the various steps of verifications and validations involved in EV development.	(7)
12	Elaborate the various tests regulations involved in EV commissioning.	(7)

222EEE012	EMBEDDED PROCESSORS AND CONTROLLERS	Category	L-T-P-C	YOI
		Program Elective 3	3-0-0-3	2022

Preamble: Nil

Course Prerequisites: Nil

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

CO 1	Design real time embedded systems by analysing the characteristics of different computing elements in embedded system.
CO 2	Identify the unique characteristics of real time operating systems and evaluate the need for real time operating system
CO 3	Identify and characterize architecture of ARM MCU
CO 4	Apply the knowledge gained for Programming ARM Processor for different applications.
CO 5	Analyse various examples of embedded systems based on ARM processor.

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3		3	3	2		
CO 2	3		3	3	2		
CO 3	3		3	3	2		
CO 4	3		3	3	2		
CO 5	3		3	3	2		

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Apply	70%	100	40	60	2.5 hours
Analyse	20%				
Evaluate	10%				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred)	:15 marks
Course based task/Seminar/Data collection and interpretation	:15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.)	:10 marks

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the University.

Part A: 5 numerical/short answer questions with 1 question from each module, (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. *Each question can carry 5 marks.*

Part B: 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. *Each question can carry 7 marks.*

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example, if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

SYLLABUS
MODULE I
Embedded System Organization: Embedded computing – characteristics of embedded computing applications – Introduction to embedded system design- architecture embedded system - Overview of Processors and hardware units in an embedded system – Selection of processor, Memory- I/O devices, Communication protocols SPI, I2C, CAN etc. Embedded system design and development process- Embedded System On Chip (SOC)- Build process- Challenges in embedded system design, optimising design metrices- Hardware software co-design- Design technologies, Design examples Software Tools, IDE, Linking and Locating software, Choosing the right platform-Testing, Simulation Debugging Techniques and Tools, Laboratory Tools and target hardware debugging, Emulators
MODULE II
Embedded Programming Concepts and RTOS: Programming Concepts -Assembly language, C program elements, Macros and functions, data types data structures Loops and Pointers Object oriented Programming, Embedded programming in C++ Operating System Basics, Types of Operating Systems, Real Time Operating System, Tasks, Process and Threads, Multi processing and Multi-tasking RTOS Task scheduling models, Handling of task scheduling and latency and deadlines as performance metrics, Co-operative Round Robin Scheduling, Case Studies of Programming with RTOS
MODULE III
Architecture and Programming of ARM: Introduction to ARM core architectures, ARM extension, family, Pipeline, memory management, Bus architecture, Programming model, Registers, Operating modes, instruction set, Addressing modes, memory interface. Programming of ARM, Read Write Memory Access, Basic programming using Online/Offline platforms
MODULE IV
On Chip Peripherals and Interfacing Lpc2148: Internal Architecture of ARM LPC 2148, Study of on-chip peripherals – Input/ output ports, Timers, Interrupts, on-chip ADC, DAC, RTC modules, WDT, PLL, PWM,USB, I2C, SPI, CAN etc Programming GPPIO, Timer programming, PWM Unit programming ARM 9, ARM Cortex -M3
MODULE V
Embedded Control Applications -Case Studies: Embedded Controller Programmable interface with A/D & D/A interface; Digital voltmeter, -PWM motor speed controller, serial communication interface Feedback control system, relay control unit, driving electrical appliances like motors, bulb, pump, etc *Case Studies- Embedded system in automobile, Adaptive cruise control, Vison controlled Robot, Ball following Robot* *Course Project: Develop an embedded control application using ARM Platform.*
Text book:
References: 1. Jonathan Valvano, Embedded Microcomputer Systems Real Time Interfacing, Third Edition Cengage Learning, 2012 2. Raj Kamal, Embedded Systems-Architecture, programming and design, 3rd edition, TMH.2017 3. Lyla B Das, Embedded Systems an Integrated Approach, Pearson, 2013 4. David E. Simon, An Embedded Software Primer‖, Pearson Education,2000. 5. Steve Heath, Butterworth Heinenann, Embedded systems design: Real world design Newton mass USA 2002

COURSE PLAN

No.	Topic	No. of Lectures
1	**MODULE I Embedded System Organization (8 hours)**	
1.1	Embedded computing – characteristics of embedded computing applications – Introduction to embedded system design-architecture embedded system - Overview of Processors and hardware units in an embedded system – Selection of processor, Memory- I/O devices	2
1.2	Communication protocols SPI, I2C, CAN etc.	1
1.3	Embedded system design and development process -Embedded System on Chip (SOC), Build process, Challenges in embedded system design, optimising design metrices, Hardware software co-design, Design technologies, design examples	2
1.4	Software Tools, IDE, Linking and Locating software, Choosing the right platform	1
1.5	Testing, Simulation Debugging Techniques and Tools, Laboratory Tools and target hardware debugging, Emulators	2
2	**MODULE II Programming Concepts and RTOS (8 hours)**	
2.1	Programming Concepts -Assembly language, C program elements, Macros and functions, data types data structures Loops and Pointers.	1
2.2	Object oriented Programming, Embedded programming in C++ and JAVA	1
2.3	Operating System Basics, Types of Operating Systems, Real Time Operating System (RTOS), Tasks, Process and Threads, Multi processing and Multi-tasking	2
2.4	RTOS Task scheduling models, Handling of task scheduling and latency and deadlines as performance metrics	2
2.5	Co-operative Round Robin Scheduling, Case Studies of Programming with RTOS	2
3	**MODULE III Architecture and Programming of ARM (8 hours)**	
3.1	Features and Architecture of ARM, RISC vs CISC, Modes of operation	2
3.2	ARM assembly language, Addressing Modes, Instruction set	2
3.3	Programming of ARM, ALP, C, Basic programming using Online/Offline platforms	2
3.4	Read Write Memory Access, Multiple register load and store	2
4	**MODULE IV Peripheral programming of ARM (8 hours)**	
4.1	Internal Architecture and features of ARM LPC 214X family	2
4.2	Peripherals inside the chip, GPIO, Timer, Interrupt, UART, PWM	2
4.3	Programming GPPIO, Timer programming	2
4.4	PWM Unit programming, ARM 9, ARM Cortex -M3	2
5	**Embedded Control Applications -Case Studies (8 hours)**	
5.1	Embedded Controller Programmable interface with A/D & D/A interface, Digital voltmeter, -PWM motor speed controller, serial communication interface	2
5.2	Feedback control system, relay control unit, driving electrical appliances like motors, bulb, pump, etc.	2
5.3	Case study -Embedded system in automobile, Adaptive cruise control	2
5.4	Case study -Vison controlled Robot, Ball following Robot	2

MODEL QUESTION PAPER

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR		
222EEE012 EMBEDDED PROCESSORS AND CONTROLLERS		
Max. Marks: 60		**Time: 2.5 Hrs.**
Sl.	**Part A (Answer all questions)**	**Marks**
1	Differentiate between independent design and codesign concepts	(5)
2	Illustrate with examples the advantages of writing embedded firmware in C.	(5)
3	Compare features of various ARM architectures	(5)
4	Generate an asymmetric square wave at four pins of PORT P0 using software delay	(5)
5	Develop a block schematic diagram for implementing vison-controlled	(5)
	Part B (Answer any five questions)	
6	Choose appropriate hardware units needed for the following embedded applications a) Robot b) Motor Control and c) Digital camera. Justify your answer,	(7)
7	With a flow chart model illustrate the embedded program development process from high level language to machine level language	(7)
8	Analyse the distinct features of real time operating system that makes it suitable for embedded applications	(7)
9	With the help of a neat diagram explain the architecture ARM processor	(7)
10	Generate PWMs at the six output pins of PWM unit with duty cycles of 40 and 50%	(7)
11	Design an embedded system for Adaptive cruise control and explain the details	(7)
12	Write an embedded C program to interface a single switch and display its status through a relay, Buzzer and LED	(7)

222EEE008	DESIGN OF POWER ELECTRONIC SYSTEM	Category	L-T-P-C	YOI
		Program Elective 4	3-0-0-3	2022

Preamble: Proper design and selection of power electronic components is crucial for the successful and reliable operation of power electronic products. This course enables the students to design suitable gate drives, power stage and cooling systems for power electronic converters meeting EMC standards. A basic course on Power Electronics is desirable as prerequisites for the course.

Course Prerequisites: Nil

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

CO 1	Develop gate drive schemes for different types of switching devices after understanding pertinent limitations of simple drive schemes
CO 2	Analyse different gate drive schemes and design protection circuits and snubbers
CO 3	Do loss calculation and design cooling systems
CO 4	Design of magnetics, filter capacitors and bus bars
CO 5	Design of power converters for Electromagnetic Compatibility

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	1		3				
CO 2	1		2		3		
CO 3	1		2		3		
CO 4	2	1			3		
CO 5		1		3	2		

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Apply	25%	100	40	60	2.5 hours
Analyse	25%				
Evaluate	25%				
Create	25%				

Evaluation shall only be based on application, analysis or design-based questions (for both internal and end semester examinations)

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred)	:15 marks
Course based task/Seminar/Data collection and interpretation	:15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.)	:10 marks

End Semester Examination Pattern: 60 marks

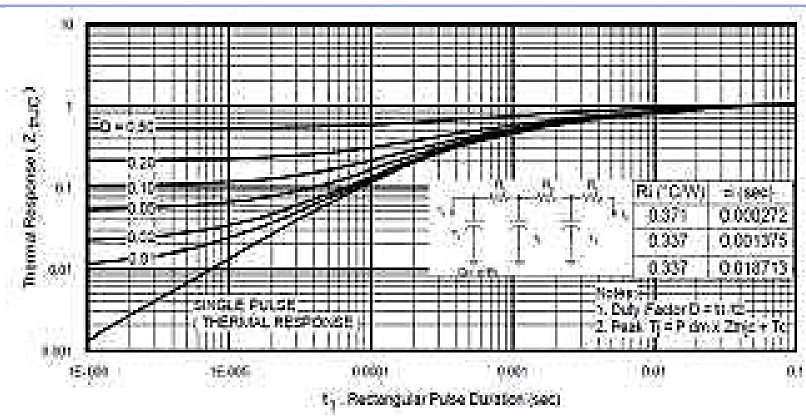
There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks. Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course

shall be normalized accordingly. For example, if the average end semester mark % for a core course is 40, then the maximum eligible mark
% for an elective course is 40+20 = 60 %.

SYLLABUS
MODULE I (9 hrs)
High frequency diodes- reverse recovery issues- fast and soft recovery- schottky diodes-loss computation in diodes- base/gate drive requirements - design of base/gate drive for Power transistors, MOSFET and IGBTs- dc coupled drive circuits- isolated drive circuits, bootstrapping - cascode transistor driver- gate drive considerations for SiC MOSFET- Gate drive power requirements- Protection in drive circuits- dead time requirements-overcurrent and desaturation protection- Noise suppression- ferrite beads- pcb layout considerations for gate drives
MODULE II (7 hrs)
Snubber circuits- Need for snubber- diode snubbers - Safe Operating Area (SOA) of switching devices- Device loss computation with and without snubber- design of turn-off and turn-on snubbers- energy recovery snubbers- snubber for bridge circuit configurations
MODULE III (7 hrs)
Cooling and design of heat sinks- heat transfer by conduction, radiation and convection-thermal analogy- control of device temperature- selection of heat sink- thermal resistance due to radiation and convection-natural cooling- Forced air cooling- pulsed power and transient thermal impedance
MODULE IV (9 hrs)
Design of inductors -selection of core material and size- core loss and winding losses-reduction of skin effect- leakage inductance- design of high frequency transformers for sine wave and square wave inverters, push-pull, half bridge, full bridge, fly back and forward converters- selection of filter capacitors- bus bars- Case study: design of buck converter, quadratic buck, fly black and single phase PWM rectifier
MODULE V (8 hrs)
EMI and EMC- Introduction- characteristics of switching processes of power devices-Electromagnetic compatibility (EMC)- conductive and radiative EMI- standards- reduction of EMI- common mode filter-LISN- Shielding of cables and transformers- PCB layout considerations - Case study: buck converter, forward and fly black converters
Text book:
References: 1. Ned Mohan, Tore M. Undeland and William P. Riobbins, “Power Electronics—Converters, Applications and Design” Third Edition, John Wiley and Sons. Inc2014 2. L. Umanand, “Power Electronics-Essentials and Applications”, Wiley, 2014 3. Daniel W. Hart, Power Electronics, Tata McGraw-Hill Education, 2011. 4. H.W. Whittington et al., “Switched Mode Power Supplies- Design and Construction”, University Press, 1997 5. Francois Costa et al., “Electromagnetic compatibility in Power Electronics”, Wiley Iste, 2014 6. Joseph Vithayathil, “Power Electronics-Principle and Applications”, Tata McGraw Hill Education Pvt Ltd, 2010.

COURSE PLAN		
No.	**Topic**	**No. of Lectures**
1	**MODULE I (9 hours)**	
1.1	High frequency diodes- reverse recovery issues- fast and soft recovery- schottky diodes- loss computation in diodes	1
1.2	Base drive requirements - design of base drive for Power	2

	transistors- dc coupled drive circuits- isolated drive circuits, cascode driver	
1.3	Gate drive requirements- Design of base gate drive for MOSFETs and IGBTs- dc coupled drive circuits- isolated drive circuits, bootstrapping	2
1.4	Gate drive considerations for SiC MOSFET	1
1.5	Gate drive power requirements	1
1.6	Protection in drive circuits- dead time requirements- overcurrent and desaturation protection	1
1.7	Noise suppression- ferrite beads- PCB layout considerations for gate drives	1
2	**MODULE II (7 hours)**	
2.1	Snubber circuits- Need for snubber- diode snubbers	2
2.2	Safe Operating Area (SOA) of switching devices- device loss computation with and without snubbers	1
2.3	Design of turn-off and turn-on snubbers	2
2.4	Energy recovery snubbers	1
2.5	snubber for bridge circuit configurations	1
3	**MODULE III (7 hours)**	
3.1	Cooling and design of heat sinks- heat transfer by conduction, radiation and convection	1
3.2	Thermal analogy- control of device temperature	1
3.3	Selection of heat sink	1
3.4	Thermal resistance due to radiation and convection- Natural cooling	2
3.5	Forced air cooling of heat sinks	1
3.6	Pulsed power and transient thermal impedance	1
4	**MODULE IV (9 hours)**	
4.1	Design of inductors -selection of core material and core size	1
4.2	Core loss and winding losses	1
4.3	Reduction of skin effect and leakage inductance	1
4.4	Design of high frequency transformers for sine wave and square wave inverters	1
4.5	Design of high frequency transformer for push-pull, half bridge, full bridge	1
4.6	Design of high frequency transformers for Fly back and forward converters	1
4.7	Selection of filter capacitors	1
4.8	Design of bus bars	1
4.9	Case study: design of buck converter, quadratic buck, fly black converter and single phase PWM rectifier	1
5	**MODULE V (8 hours)**	
5.1	EMI and EMC- Introduction	1
5.2	Characteristics of switching processes of power devices	1
5.3	Electromagnetic compatibility(EMC)- conductive and radiative EMI- standards	1
5.4	Reduction of EMI- common mode filter- LISN	2
5.5	Shielding of cables and transformers	1
5.6	PCB layout considerations	1
5.7	Case study: buck converter, forward and fly black converters	1

MODEL QUESTION PAPER		
SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR		
222EEE008 DESIGN OF POWER ELECTRONIC SYSTEMS		
Max. Marks: 60		Time: 2.5 Hrs.
Sl.	**Part A** **(Answer all questions)**	**Marks**
1	List the important drive requirements of a good BJT drive CO1BL1	(5)
2	An RCD snubber is used in a MOSFET based laptop car battery adapter (12 V to 19 V, 2.5 A current output). Calculate the turn-off loss with and without the snubber. The MOSFET is switched at 100kHz and the MOSFET has a turn-off delay time of 90ns and current fall time of 80ns. CO2 BL2	(5)
3	What do you mean by thermal resistance? Explain how its value can be reduced in a heat sink? Also explain the electrical equivalent model of a typical heat sink arrangement CO3BL1	(5)
4	Calculate the skin depth at 2kHz, and at 200kHz for enamelled copper conductors and hence suggest the conductor(s) size to carry a current of 5A RMS at these frequencies. Justify the selection CO4 BL3	(5)
5	Explain the PCB layout considerations in a flyback converter for EMI reduction CO5BL1	(5)
	Part B **(Answer any five questions)**	
6	(a) A MOSFET needs 250nC of total gate charge to turn ON. Determine the gate current needed if the MOSFET needs to be turned ON in about 350ns. Draw a suitable gate drive scheme. If the MOSFET is used in an application where the switching frequency is 25kHz, what is the minimum duty cycle percentage possible if the device turn-OFF time is 250ns. (3) CO1BL2 (b) What do you mean by cascode-connected drive circuits? Explain (4) CO1BL1	(7)
7	(a) Explain the need for snubber network for fast recovery diodes and obtain design equations for the snubbers (3) CO2BL1 (b) Draw the instantaneous voltage, current and power waveforms across a typical IGBT during turn-off, without and with an RCD snubber. Determine the value of turn-off snubber capacitor for which total loss at turn-off is minimum (4) CO2BL2	(7)
8	 (a) A power pulse of 500W with a 10μs duration and a duty cycle of 0.2 occurs in a MOSFET that has transient thermal	(7)

		resistance characteristics as shown in figure below. Determine the maximum junction temperature, if the case temperature is 80°C. (3) CO3BL3	
	(b)	A student used IRFZ44 MOSFET without any heatsink in a switching regulator application where the switching loss is 1.5W and conduction loss is 0.85W. The thermal resistance RΘj-a of the MOSFET is 62 °C/W. What is the typical temperature at the junction at this operating condition? Is the design acceptable? Give your comments. (4) CO3BL3	
9	(a)	Select suitable airgap length and number of turns for the transformer in a forward converter. Use EE42/21/20 ferrite core. It is given that battery Voltage=12V, Output voltage=200V, Output power=20W, Switching frequency=25kHz. Make suitable assumptions (3) CO4BL4	(7)
	(b)	An inductor is constructed with a U-shaped ferrite core. The core has an area of cross section 200mm2 and mean magnetic path length of 12 cm. The relative permeability of the core is 3000. Calculate the inductance when 55 turns are used for the coil. What is the value of inductance when an air-gap of 4mm is introduced in the flux path? (4) CO4BL2	
10	(a)	Design and select each component of a suitable dc-dc converter with input voltage 100V and output voltage of 10V. Output power = 2000W. Switching frequency 10 kHz, Assume all other required data. Justify your selection of components. (3) CO5BL4	(7)
	(b)	Draw the circuit diagram of a forward converter operating at 50kHz, power being drawn from 230V, 50Hz mains. Identify the possible conducted noise emission sources and explain the means to reduce EMI (4) CO5BL1	
11	(a)	Illustrate the design of the gate drive circuit for For Si MOSFET (3) CO4BL1	(7)
	(b)	In a flyback converter, the dc input voltage is 320V and output voltage is 20V. The transformer has a turns ratio of 10:1 and a leakage inductance of 400μH as measured on the high voltage side. The transistor which can be considered as an ideal switch, is driven by a 50KHz square wave. The fast recovery diode of the converter has a reverse recovery time of 100ns (i) Draw the circuit diagram and an equivalent circuit suitable for diode snubber design calculations (ii) Determine suitable snubber capacitor and resistance for the diode (4) CO4BL3	
12	(a)	Illustrate the design of the gate drive circuit for For SiC MOSFET (3) CO1BL1	(7)
	(b)	A 5V microcontroller PWM port has current sourcing/sinking capability of 10mA only. Hence, a transistor-based gate drive circuit is needed as the gate driver to drive a power MOSFET in a 5V to 19V boost converter application (i) Draw the circuit diagram of the microcontroller interface and the driver (ii) Design a gate driver circuit so that the MOSFET can operate properly at a switching frequency of 100kHz. Make suitable assumptions (4) CO2BL4	

222EEE020	HYDROGEN AND FUEL CELL TECHNOLOGIES	Category	L-T-P-C	YOI
		Program Elective 4	3-0-0-3	2022

Preamble: This course introduces the basics and technologies of Hydrogen and fuel cell systems.

Course Prerequisites: Nil

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

CO 1	Understand principle and working of fuel cells
CO 2	Describe the construction of different types of fuel cells
CO 3	Analyse the electrochemical kinetics and thermodynamics of fuel cells
CO 4	Design fuel cell-based systems
CO 5	Understand production, storage, transport and utilisation of Hydrogen as a fuel

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
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

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Understand	60%	100	40	60	2.5 hours
Apply	20%				
Analyse	20%				
Evaluate	--				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred)	:15 marks
Course based task/Seminar/Data collection and interpretation	:15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.)	:10 marks

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions, with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions, with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks.

SYLLABUS

MODULE I (8 hours)

Basics: Fuel cell definition –difference between batteries and fuel cells - fuel cell history, Components of fuel cells-principle of working of fuel cell - Performance characteristics of fuel cells- Stack configurations and fuel cell system.

MODULE II (8 hours)

Fuel cell types –alkaline fuel cell - polymer electrolyte membrane type fuel cell Phosphoric acid fuel cell – molten carbonate fuel cell - solid oxide fuel cell - Geometries of solid oxide fuel cells - planar and tubular – Applications.

MODULE III (8 hours)
Thermodynamics of fuel cells – introduction to electrochemical kinetics - transport related phenomena, Conservation equations for reacting multi component systems.
MODULE IV (8 hours)
Fuel cell system design – optimization and economics Hydrogen – merit as a fuel – applications - suitability of hydrogen as a fuel – fuel cell as energy conversion device
MODULE V (8 hours)
Hydrogen production methods - from fossil fuels – electrolysis – thermal decomposition – photochemical – photo catalytic – hybrid – Hydrogen Storage – metal hydrides- metallic alloy hydrides – Carbon nano-tubes. Hydrogen Transport-– Road – railway – pipeline – ship.

Text book:

1. Leo J. M. J. Blomen, Michael N. Mugerwa, Fuel Cell System, Plenum Press, New York, 1993.
2. G. D. Rai, Non-Conventional Energy Sources, Khanna Publishers, 2010.
3. J. Appleby and F. R. Foulkers, Fuel Cell Handbook, Van Nostrand, 1989.
4. Sorensen, Hydrogen and Fuel Cells, Elsevier Academic Press, USA, 2005.

References:

1. R. Narayan, B. Viswanathan, Chemical and Electrochemical Energy Systems, University Press India Ltd, 1998.
2. D P. Kothari, K. C. Singhal, Rakesh Rajan, Renewable energy sources and emerging technologies, nd edition, 2013.
3. B H Khan, Non-Conventional Energy Resources, 2nd edition, TMH 2013.

COURSE PLAN

No.	Topic	No. of Lectures
1	**MODULE I (8 hours)**	
1.1	Basics: Fuel cell definition –difference between batteries and fuel cells	2
1.2	fuel cell history, Components of fuel cells - principle of working of fuel cell	2
1.3	Performance characteristics of fuel cells-	2
1.4	Stack configurations and fuel cell system.	2
2	**MODULE II (8 hours)**	
2.1	Fuel cell types –alkaline fuel cell -–	2
2.2	Polymer electrolyte membrane fuel cell - Phosphoric acid fuel cell	2
2.3	Molten carbonate fuel cell - solid oxide fuel cell -	2
2.4	Geometries of solid oxide fuel cells - planar and tubular – Applications	2
3	**MODULE III (8 hours)**	
3.1	Thermodynamics of fuel cells	3
3.2	Introduction to electrochemical kinetics – transport related phenomena,	3
3.3	Conservation equations for multicomponent systems	2
4	**MODULE IV (8 hours)**	
4.1	Fuel cell system design – optimization and economics	3
4.2	Hydrogen – merit as a fuel – applications	2
4.3	Suitability of hydrogen as a fuel – fuel cell as an energy conversion device	3
5	**MODULE V (8 hours)**	
5.1	Hydrogen production methods - from fossil fuels – electrolysis	2
5.2	Thermal decomposition – photochemical – photocatalytic -hybrid –	2

5.3	Hydrogen Storage – metal hydrides- metallic alloy hydrides – Carbon nano-tubes.	2
5.4	Hydrogen Transport-– Road – railway – pipeline – ship	2

MODEL QUESTION PAPER		
SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR		
222EEE020 HYDROGEN AND FUEL CELL TECHNOLOGIES		
Max. Marks: 60		**Time: 2.5 Hrs.**
Sl.	**Part A** **(Answer all questions)**	**Marks**
1	What is a fuel cell? Compare it with a battery.	(5)
2	Explain the reactions taking place in an alkaline fuel cell	(5)
3	Discuss the various methods to improve the kinetic performance of a fuel cell.	(5)
4	List the important qualities required for an effective fuel cell catalyst material	(5)
5	Compare photo chemical and photo catalytic method of hydrogen production	(5)
	Part B **(Answer any five questions)**	
6	Explain the design of a fuel cell stack and fuel cell system.	(7)
7	Derive expressions for temperature dependence of the reversible voltage obtained from a fuel cell.	(7)
8	With a neat sketch explain the working of molten carbonate fuel cell.	(7)
9	Write a note on the characteristics of fuel cell charge transport resistance.	(7)
10	Explain the conservation equations for a multicomponent system.	(7)
11	Explain the process of hydrogen production from fossil fuels.	(7)
12	Elaborate on different methods for hydrogen storage	(7)

222EEE022	EV CHARGING SYSTEMS	Category	L-T-P-C	YOI
		Program Elective 4	3-0-0-3	2022

Preamble: The key aspect of EV charging systems is the efficiency and effectiveness of energy transfer. This course equips students to understand and analyze the various modes and equipment used in electric vehicle charging. It covers the classification, sizing, and standards of chargers, including communication protocols and their role in ensuring interoperability. Additionally, the course addresses the planning and implementation of public charging infrastructure, along with emerging technologies and future trends, such as wireless charging and the integration of renewable energy sources.

Course Prerequisites: Nil

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

CO 1	Understand the various components of Electric vehicle charging system
CO 2	Comprehend the different types of Electric vehicle chargers and their standards
CO 3	Interpret the various communication protocols used in Electric vehicle charging
CO 4	Familiarize with the recent trends in Electric vehicle charging

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	3				
CO 2	3	2	3	2	2		
CO 3	3	2	3	2	2	2	
CO 4	3	2	3				
CO 5	3	2	3				

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Apply	60%	100	40	60	2.5 hours
Analyse	20%				
Evaluate	20%				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred)	:15 marks
Course based task/Seminar/Data collection and interpretation	:15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.)	:10 marks

End Semester Examination Pattern: 60 marks

There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question carries 7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example, if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

SYLLABUS
MODULE I (9 hours) Introduction to EV charging
Introduction to EV charging Electric Vehicle Charging; Charging Modes; Electric Vehicle Supply Equipment (EVSE): Types, Components of EV Battery Chargers; Challenges in Electric Vehicle Charging
MODULE II (8 hours) Charger sizing and standards
Charger sizing and standards Charger Classification; Slow Charging and Fast Charging; DC Charging and AC Charging; Selection and Sizing of Chargers: Charger Connectors and Cables; Charging Standards: Connectors, Supply Equipment; EMI/EMC; Testing Methods for Chargers and EVSE
MODULE III (9 hours) EV charger communications protocols
EV charger communications protocols Open Charge Point Protocol (OCPP); Open System Interconnection Layer Model (OSI); Adapted PWM Signal based Low-level Communication; PLC based High-level Communication; CAN Communication; Billing and Authentication
MODULE IV (9 hours) Public charging infrastructure
Public charging infrastructure Location, Planning and Implementation of Public Charging Stations; Components; Selection and Sizing - HT/LT Equipment & Cables; Protection; Safety Standards: Policy and Regulatory Aspects; EV Charging Station and their Business Models; Economic Aspects; Major Challenges
MODULE V (8 hours) Future frontiers in EV charging
Future frontiers in EV charging Bulk Charging; Battery Swapping; Wireless Charging; EVs as Distributed Storage Resources: Grid to Vehicle (G2V) and Vehicle to Grid (V2G), V2X Concept, Integration of Charging Station with Renewable Sources and its Impact on the Grid
Text book: 1. Iqbal Husain, “Electric and Hybrid Vehicles: Design Fundamentals”, 3rd Edition, CRC Press, 2021 2. Code of Practice for Electric Vehicle Charging Equipment Installation, 4th Edition, IET, 2020.
References: 1. Sheldon S. Williamson, “Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles”, 1st Edition, Springer, 2013. 2. Tom Denton, “Automotive Electrical and Electronic Systems”, 5th Edition, Routledge, 2018 3. Wolfhard Lawrenz, “CAN System Engineering: From Theory to Practical Applications”, Springer, 2nd Edition, 2013.

COURSE PLAN		
No.	**Topic**	**No. of Lectures**
1	**MODULE I (6 hours)**	
1.1	Electric Vehicle Charging;	1
1.2	Charging Modes;	2
1.3	Electric Vehicle Supply Equipment: Types	2
1.4	Components of EV Battery Chargers;	2
1.5	Challenges in Electric Vehicle Charging.	2
2	**MODULE II (8 hours)**	
2.1	Charger Classification; Slow Charging and Fast Charging;	2
2.2	DC Charging and AC Charging; Selection and Sizing of Chargers	2
2.3	Charger Connectors and Cables; Charging Standards: Connectors,	2

2.4	Supply Equipment; EMI/EMC; Testing Methods for Chargers and EVSE	2
3	**MODULE III (8 hours)**	
3.1	Open Charge Point Protocol (OCPP);	1
3.2	Open System Interconnection Layer Model (OSI)	2
3.3	Adapted PWM Signal based Low-level Communication	2
3.4	PLC based High-level Communication	2
3.5	CAN Communication; Billing and Authentication	2
4	**MODULE IV (7 hours)**	
4.1	Location, Planning and Implementation of Public Charging Stations;	1
4.2	Components; Selection and Sizing	2
4.3	HT/LT Equipment & Cables; Protection; Safety Standards:	2
4.4	Policy and Regulatory Aspects;	2
4.5	EV Charging Station and their Business Models; Economic Aspects; Major Challenges	2
5	**MODULE V (9 hours)**	
5.1	Bulk Charging; Battery Swapping; Wireless Charging;	2
5.2	EVs as Distributed Storage Resources	2
5.3	Grid to Vehicle (G2V) and Vehicle to Grid (V2G), V2X Concept.	2
5.4	Integration of Charging Station with Renewable Sources and its Impact on the Grid	2

MODEL QUESTION PAPER

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

222EEE022 EV CHARGING SYSTEMS

Max. Marks: 60 **Time: 2.5 Hrs.**

Sl.	**Part A (Answer all questions)**	**Marks**
1	Explain the different modes of Electric Vehicle charging.	(5)
2	Differentiate between AC charging and DC charging for electric vehicles.	(5)
3	What is the Open Charge Point Protocol, and how does it facilitate communication between electric vehicle chargers and central systems?	(5)
4	What are the key factors to consider when selecting a location for a public electric vehicle charging station?	(5)
5	What is battery swapping in electric vehicles, and how does it differ from traditional bulk charging?	(5)
	Part B (Answer any five questions)	
6	Discuss the components of Electric Vehicle Supply Equipment and the challenges associated with Electric Vehicle charging.	(7)
7	Explain the selection and sizing criteria for electric vehicle chargers, including the types of connectors and cables used.	(7)
8	Describe the role of the Open System Interconnection model in electric vehicle communication systems, focusing on the different types of communication methods used, such as PWM, PLC, and CAN.	(7)
9	Discuss the safety standards and protection measures required for the installation and operation of public EV charging stations, including the selection and sizing of HT/LT equipment and	(7)

	cables.	
10	Analyze the economic aspects and business models of EV charging stations, highlighting the major challenges faced in their implementation.	(7)
11	Explain the V2G and V2X concepts, and discuss how EVs can function as distributed storage resources within the energy grid.	(7)
12	Analyze the integration of EV charging stations with renewable energy sources and its potential impact on the stability and efficiency of the power grid.	(7)

222EEE056	ELECTRIC AND HYBRID VEHICLES	Category	L-T-P-C	YOI
		Inter. Elective	3-0-0-3	2022

Preamble: To help the students to obtain a comprehensive overview of Electric and Hybrid Vehicles.

Course Prerequisites: Nil

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

CO 1	Explain the basics of Electric and hybrid electric vehicles.
CO 2	Select an appropriate energy storage strategy for a particular EV/HEV.
CO 3	Explain battery management techniques and EV charging standards.
CO 4	Describe e-mobility and different charging connectors.
CO 5	Describe the latest trends in E–vehicle communication and networking

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	3			3	2	
CO 2	2	3			2	2	
CO 3	2	3			2	2	
CO 4	2	3			3	2	
CO 5	2	3			3	2	

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Understand	60%	100	40	60	2.5 hours
Apply	20%				
Analyse	20%				
Evaluate	--				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred)	:15 marks
Course based task/Seminar/Data collection and interpretation	:15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.)	:10 marks

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions, with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions, with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks.

SYLLABUS

MODULE I: INTRODUCTION TO HEV AND EV (10 hours)

Introduction to hybrid and electric vehicles:
Review of Conventional Vehicle: Vehicle Power Plant and Transmission Characteristics, Mathematical Model to represent vehicle performance, Tractive effort in normal driving.
Introduction to Electric Vehicles and Hybrid Electric Vehicles: General Configuration of Electric Vehicles, Types of EV Drive train and power flow control, Energy saving potential of Hybrid Electric Drive train, Architecture of Hybrid Electric Drive Trains, Power flow control in HEV.

Electric Drives: Configuration and control of - DC Motor drives, Induction Motor drives, Permanent Magnet Motor drives, and Switched reluctance motors.
MODULE II: ENERGY STORAGE AND SIZING THE DRIVE SYSTEM (8 hours)
Energy storage and sizing the drive system: Energy storage system: Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery-based energy storage and its analysis, Fuel Cell-based energy storage and its analysis, Supercapacitors and ultracapacitors, Hybridization of different energy storage devices. Sizing the drive system: Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor, Sizing the power Electronics, and selecting the energy storage technology.
MODULE III: ENERGY MANAGEMENT SYSTEM AND EV CHARGING (9 hours)
Energy management system and ev charging standards: Control System for Electric and Hybrid Electric Vehicles: Control architecture, Components, Different Electronic Control Units (ECUs), Control Area Network (CAN). Battery Management System: Battery Management System, Requirement of Battery Monitoring, Battery State of Charge Estimation methods, Energy & Power estimation, Battery thermal management system, Battery Cell equalization problem. EV charging standards: V2G, G2V, V2B, V2H.
MODULE IV: E-MOBILITY AND CONNECTORS (6 hours)
E-mobility and connectors: Introduction: E-mobility, Connected Mobility and Autonomous Mobility, Indian E-mobility Roadmap. Policy: EVs in infrastructure system, integration of EVs in smart grid, social dimensions of EVs. Connectors: Types of EV charging connectors- North American EV Standards, DC Fast charge CCS (Combined Charging System), Tesla, European EV Plug Standards.
MODULE V: VEHICULAR NETWORKS AND COMMUNICATION (7 hours)
Vehicular networks and communication: Vehicular Communications: Intelligent Transportation Systems: IEEE 802.11p-ITSIVC: Inter Vehicle Communications - Mobile Wireless Communications and Networks-Architecture Layers- Communication Regime.V2V, V2I-VANETWAVE; DSRC - Information in The Vehicle Network Routing-Physical Layer Technologies-Medium Access for Vehicular Communications- Security Applications and Case Studies
Text book: 1. Iqbal Hussain, Electric & Hybrid Vehicles – Design Fundamentals, CRC Press, 2011 2. Rand D.A.J, Woods, R & Dell RM Batteries for Electric vehicles, research studies press, UK, 1998.
References: 1. Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electrical and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004. 2. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.

COURSE PLAN

No.	Topic	No. of Lectures
1	**MODULE I (10 hours)**	
1.1	Review of Conventional Vehicle: Vehicle Power Plant and Transmission Characteristics	1
1.2	Mathematical Model to represent vehicle performance, Tractive effort in normal driving.	1
1.3	Introduction to Electric Vehicles and Hybrid Electric Vehicles: General Configuration of Electric Vehicles, Types of EV Drive train and power flow control,	2

1.4	Energy saving potential of Hybrid Electric Drive train, Architecture of Hybrid Electric Drive Trains, Power flow control in HEV.	2
1.5	Electric Drives: Configuration and control of - DC Motor drives, Induction Motor drives, Permanent Magnet Motor drives, and Switched reluctance motors.	4
2	**MODULE II (8 hours)**	
2.1	Energy storage system: Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery-based energy storage and its analysis	3
2.2	Fuel Cell-based energy storage and its analysis	1
2.3	Supercapacitors and ultracapacitors, Hybridization of different energy storage devices.	2
2.4	Sizing the drive system: Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor, Sizing the power Electronics, and selecting the energy storage technology.	2
3	**MODULE III (9 hours)**	
3.1	Control System for Electric and Hybrid Electric Vehicles: Control architecture, Components, Different Electronic Control Units (ECUs), Control Area Network (CAN).	2
3.2	Battery Management System: Battery Management System, Requirement of Battery Monitoring,	2
3.3	Battery State of Charge Estimation methods, Energy & Power estimation,	2
3.4	Battery thermal management system, Battery Cell equalization problem.	2
3.5	EV charging standards: V2G, G2V, V2B, V2H.	1
4	**MODULE IV (6 hours)**	
4.1	Introduction: E-mobility, Connected Mobility and Autonomous Mobility, Indian E-mobility Roadmap.	2
4.2	Policy: EVs in infrastructure system, integration of EVs in smart grid, social dimensions of EVs.	2
4.3	Connectors: Types of EV charging connectors- North American EV Standards,	1
4.4	DC Fast charge CCS (Combined Charging System), Tesla, European EV Plug Standards.	1
5	**MODULE V (7 hours)**	
5.1	Vehicular Communications: Intelligent Transportation Systems: IEEE 802.11p-ITSIVC:	2
5.2	Inter-Vehicle Communications - Mobile Wireless Communications and Networks- Architecture Layers	1
5.3	Communication Regime.V2V, V2I-VANETWAVE; DSRC - Information In The Vehicle Network Routing-Physical Layer Technologies-	2
5.4	Medium Access for Vehicular Communications- Security Applications and Case Studies	2

MODEL QUESTION PAPER		
SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR		
222EEE056 ELECTRIC AND HYBRID VEHICLES		
Max. Marks: 60		Time: 2.5 Hrs.
Sl.	**Part A** **(Answer all questions)**	**Marks**
1	Derive the dynamic equation of vehicle motion along the longitudinal direction. Give the expression for maximum tractive effort that the tire ground contact can support in electric and hybrid vehicles.	(5)
2	With a block diagram, describe the working of a Fuel Cell Electric Vehicle Drive system.	(5)
3	Discuss about battery cell equalization problem	(5)
4	Discuss about past trends and current status of the Electric vehicle market in India. Mention a few Electric vehicle-programmes and policies that may foster EVs in the country.	(5)
5	Explain about wireless access in vehicle environments with IEEE 802.11p	(5)
	Part B **(Answer any five questions)**	
6	Compare various architectures of Hybrid Electric Drive Trains with neat diagrams. Mention a few advantages and disadvantages	(7)
7	Discuss the construction and principle of permanent magnet motor drives	(7)
8	Describe super capacitors and ultra-capacitors as energy storage technologies in EVs.	(7)
9	With necessary equations, explain a method for estimation of the State of Charge of a Battery.	(7)
10	Draw and explain the functional block diagram of Electric Propulsion System in electric and hybrid vehicles.	(7)
11	Elaborate the concept of Vehicle-to-Grid and Grid-to-Vehicle charging.	(7)
12	Describe vehicle-to-vehicle communication using Dedicated Short-Range Communication (DSRC) technology.	(7)

222EEE071	ELECTRIC CHARGING SYSTEMS FOR ELECTRICAL VEHICLES	Category	L-T-P-C	YOI
		Inter. Elective	3-0-0-3	2022

Preamble: The course is aimed to provide an overview of the technological concepts and regulatory frameworks related to the charging systems of Electrical Vehicle

Course Prerequisites: Nil

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

CO 1	Analyze the working of different types of controlled rectifiers
CO 2	Analyze the working of different types of choppers
CO 3	Describe the energy storage mechanisms used for EV's
CO 4	Explain the various types of chargers used for EV's
CO 5	Explain the various charging standards for EV's

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2			1		1	
CO 2	2			1		1	
CO 3	2			1		1	
CO 4	2		1	1		2	
CO 5	2		1	1		2	

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Apply	50%	100	40	60	2.5 hours
Analyse	30%				
Evaluate	20%				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred)	:15 marks
Course based task/Seminar/Data collection and interpretation	:15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.)	:10 marks

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions, with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions, with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks.

SYLLABUS
MODULE I AC-DC converters
AC-DC converters: Controlled Rectifiers (Single Phase) – Half-wave controlled rectifier with R load– 1-phase fully controlled bridge rectifier with R, RL and RLE loads (continuous conduction only) – Output voltage equation – Controlled Rectifiers (3-Phase) - 3-phase half-wave controlled rectifier with R load – 3-phase fully controlled converter with RLE load (continuous conduction, ripple free) – Output voltage equation- Waveforms for various triggering angles (analysis not required).
MODULE II DC-DC converters
DC-DC converters – Step down and Step up choppers – Single-quadrant, Two-quadrant

and Four quadrant chopper – Pulse width modulation & current limit control in dc-dc converters. Switching regulators – Buck, Boost & Buck-boost –Operation with continuous conduction mode – Waveforms – Design (switch selection, filter inductance and capacitance).
MODULE III Energy storage
Energy Storage: Introduction to energy storage requirements in Electric Vehicles- Units of Battery Energy Storage - Capacity rate- Battery based energy storage systems, Types of battery- Lifetime and Sizing Considerations - Battery Charging, Protection, and Management Systems - Fuel Cell based energy storage systems- Supercapacitors- Hybridization of different energy storage devices.
MODULE IV Charging infrastructure
Charging infrastructure: On-board chargers, Electric Vehicle Supply Equipment (EVSE) - Grid to EVSE to On-board chargers to battery pack power flow block schematic diagrams – Types of charging stations - AC Level 1 & 2, DC - Level 3, Wireless charging. Plug-in Hybrid EV, V2G concept.
MODULE V Charging Standards
Charging Standards - SAE J1772, VDE-AR-E 2623-2-2, JEVS G105-1993, Types of Connectors - CHAdeMo, CCS Type1 and 2, GB/T - pin diagrams and differences, IEC 61851 - Electric vehicle conductive charging modes, IEC 61980- Electric vehicle wireless power transfer systems, IEC 62196 -AC Couplers Configuration, Combo AC DC Couplers and IS- 17017 standards for EV charging.
Text book: 1. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003. 2. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003. 3. Mehrdad Ehsani, YimiGao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004. 4. John G. Hayes, Electric powertrain, Wiley.
References:

COURSE PLAN		
No.	**Topic**	**No. of Lectures**
1	**MODULE I AC-DC converters (8 hours)**	
1.1	Controlled Rectifiers (Single Phase) – Half-wave-controlled rectifier with R load– 1-phase fully controlled bridge rectifier with R, RL and RLE loads (continuous conduction only) –	2
1.2	Controlled Rectifiers (Single Phase) Output voltage equation – Controlled Rectifiers, Simple numeric problems	2
1.3	3-phase half-wave-controlled rectifier with R load – 3-phase fully controlled converter with RLE load (continuous conduction, ripple free)	2
1.4	Controlled Rectifiers (Three Phase) Output voltage equation- Waveforms for various triggering angles (analysis not required). Simple numeric problems	2
2	**MODULE II (DC-DC converters) (7 hours)**	
2.1	Step down and Step up choppers – Single-quadrant, Two- quadrant and Four quadrant chopper	2
2.2	Pulse width modulation & current limit control in dc-dc converters.	1
2.3	Switching regulators – Buck, Boost & Buck-boost	2
2.4	Operations with continuous conduction mode – Waveforms – Design (switch selection, filter inductance and capacitance).	2
3	**MODULE III Energy storage (9 hours)**	

3.1	Introduction to energy storage requirements in Electric Vehicles	1
3.2	Units of Battery Energy Storage - Capacity rate-	1
3.3	Battery based energy storage systems, Types of battery-	1
3.4	Lifetime and Sizing Considerations	2
3.5	Battery Charging, Protection, and Management Systems	2
3.6	Fuel Cell based energy storage systems- Super capacitors-	1
3.7	Hybridization of different energy storage devices	1
4	**MODULE IV Charging infrastructure (8 hours)**	
4.1	On-board chargers	1
4.2	Electric Vehicle Supply Equipment (EVSE) - Grid to EVSE to On-board chargers to battery pack.	1
4.3	Power flow block schematic diagrams	2
4.4	Types of charging stations - AC Level 1 & 2	1
4.5	Types of charging stations DC - Level 3,	1
4.6	Wireless charging.	1
4.7	Plug-in Hybrid EV, V2G concept	1
5	**MODULE V Charging Standards (8 hours)**	
5.1	SAE J1772, VDE-AR-E 2623-2-2, JEVS G105-1993,	2
5.2	Types of Connectors - CHAdeMo, CCS Type1 and 2,	1
5.3	GB/T - pin diagrams and differences,	1
5.4	IEC 61851 - Electric vehicle conductive charging modes	1
5.5	IEC 61980- Electric vehicle wireless power transfer systems,	1
5.6	IEC 62196 -AC Couplers Configuration, Combo AC DC Couplers	1
5.7	IS-17017 standards for EV charging.	1

MODEL QUESTION PAPER

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

222EEE071 ELECTRIC CHARGING SYSTEMS FOR ELECTRIC VEHICLES

Max. Marks: 60 **Time: 2.5 Hrs.**

Sl.	Part A (Answer all questions)	Marks
1	What is inverted mode of operation of the converter? Explain.	(5)
2	What is a two-quadrant chopper? Explain.	(5)
3	Explain about the battery management systems used in EV.	(5)
4	Draw and explain the configuration of a level-1 charger.	(5)
5	Explain the CHAdeMo charging protocol for EV.	(5)
	Part B (Answer any five questions)	
6	Draw the circuit of 3 phase fully controlled rectifier with RLE load and explain the working for α=600 with necessary waveforms. Derive the expression for average output voltage.	(7)
7	A boost converter has an input voltage of Vd=10V and an average output voltage of 20V and average load current of I0=0.5A.The switching frequency is 25kHz and and L=200μH and C=220μF.Determine (a) duty ratio (b) ripple current of the inductor (c) peak current of inductor and (d) ripple voltage of capacitor.	(7)
8	Draw the circuit of 3 phase fully controlled rectifier with RL load and explain the working for α=60 degree with necessary waveforms. Derive the expression for average output voltage.	(7)
9	Explain the working of a Buck-Boost regulator, showing relevant waveforms and derive the expression for its output voltage.	(7)

10	Explain about Fuel cell-based energy storage systems.	(7)
11	Explain the operation of level-3 battery charger with a neat circuit diagram.	(7)
12	Describe the various charging standards used for electric vehicles.	(7)

242PEE100	MINI PROJECT	Category	L-T-P-C	YOI
		Project	0-0-4-2	2024

Preamble: Mini project can help to strengthen the understanding of student's fundamentals through application of theoretical concepts and to boost their skills and widen the horizon of their thinking. The ultimate aim of an engineering student is to resolve a problem by applying theoretical knowledge. Doing more projects increases problem solving skills.

The introduction of mini projects ensures **preparedness of students to undertake dissertation**. Students should identify a topic of interest in consultation with PG Programme Coordinator that should lead to their dissertation/research project. Demonstrate the novelty of the project through the results and outputs.

The progress of the mini project is evaluated based on three reviews, two interim reviews and a final review. A report is required at the end of the semester.

Evaluation Committee - Programme Coordinator, One Senior Professor and Guide.

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

CO 1	Undertake dissertation.

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	3	2	2	2	2	3

Assessment Pattern

Sl. No	Type of evaluations	Marks	Evaluation criteria
1	Interim evaluation 1	20	
2	Interim evaluation 2	20	
3	Final evaluation by a Committee	35	Will be evaluating the level of completion and demonstration of functionality/ specifications, clarity of presentation, oral examination, work knowledge and involvement
4	Report	15	The committee will be evaluating for the technical content, adequacy of references, templates followed and permitted plagiarism level(not more than 25%)
5	Supervisor/Guide	10	
	Total Marks	**100**	

222LEE006	EV HARDWARE LAB	Category	L-T-P-C	YOI
		Laboratory	3-0-0-3	2022

Preamble: This course equips students with the skills to design and develop electric vehicle systems by providing hands-on experience with the operation and control of Electric Vehicle drives and its body parts. It includes simulation and hardware experiments to enhance troubleshooting capabilities and ensure a deep understanding of Electric Vehicle systems. The course also focuses on developing and implementing control algorithms for electric vehicle drives and power converters on digital control platforms.

Course Prerequisites: Nil

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

CO 1	Describe the performance characteristics and model dynamics of hybrid and electric vehicles.
CO 2	Examine the architecture of drivetrains and electric propulsion units in electric and hybrid vehicles.
CO 3	Analyse various energy storage devices used in hybrid and electric vehicles and select the electric drive system
CO 4	Investigate energy management strategies employed in hybrid and electric vehicles.

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3	2	2	2		2	
CO 2	3	2	2	2		2	
CO 3	2	2	2	2		2	
CO 4	3	2	2	2		2	

Assessment Pattern

The laboratory courses will be having only Continuous Internal Evaluation and carries 100 marks.

Mark distribution				Continuous Internal Evaluation Pattern: 100 marks	
Total Marks	**CIE**	**ESE**	**ESE Duration**		
100	**100**	--	--	Practical Records /outputs:	**40%**
				Regular Class Viva-Voce:	**20%**
				Final Assessment:	**40%**

Final assessment will be done by two examiners; one examiner will be a senior faculty from the same department.

Final Assessment Mark Split up will be as follows:

Preliminary work -30%
Performance – 30%
Results – 20%
Viva-20%

SYLLABUS

EXPERIMENTS

1. To perform the speed control of PMSM and Induction motor using FOC and DTC.
2. Open loop and closed loop speed control of BLDC motors.
3. To perform the speed control of Electric vehicle using throttle and analyse the torque production
4. Study of braking system in autonomous electric vehicle
5. Measurement of DC-link current, voltage and BMS data of EV
6. Measure accurate level of battery charging and its indication

7. Balancing of Cells-Active and Passive
8. Accurate measurement of three phase current using Hall effect sensors
9. Case study on thermal runaway of battery, motor and power trains.
10. Sending the EV sensor data sets into IoT cloud

Reference Books

1. Permanent Magnet Synchronous and Brushless DC Motor Drives" by R. Krishnan
2. BLDC Motor Drive Simulation and Analysis by K.R. Rajagopal
3. Accurate State-of-Charge Estimation by Kalman Filtering" by Gregory L. Plettnfranco Pistoia
4. Thermal Management of Electric Vehicle Battery Systems" by Ibrahim Dincer and Halil S. Hamut
5. Internet of Things (IoT) for Automated and Smart Applications" by Yasser Ismail

SEMESTER III

SLOT	COURSE CODE	COURSE NAME	MARKS		L-T-P	Hrs.	CREDIT
			CIA	ESE			
TRACK 1							
A*	223MEEXXX	MOOC	To be completed successfully		--	--	2
B	223AGEXXX	AUDIT COURSE	40	60	3-0-0	3	--
C	223IEE100	INTERNSHIP	50	50	--	--	3
D	223PEE100	DISSERTATION PHASE 1	100	--	0-0-17	17	11
TRACK 2							
A*	223MEEXXX	MOOC	To be completed successfully		--	--	2
B	223AGEXXX	AUDIT COURSE	40	60	3-0-0	3	--
C	223IEE100	INTERNSHIP	50	50	---	--	3
D	223PEE001	RESEARCH PROJECT PHASE 1	100	--	0-0-17	17	11
		Total	**190**	**110**		**20**	**16**

AUDIT COURSE						
SLOT	**SL NO**	**COURSE CODE**	**COURSE NAME**	**L-T-P**	**Hrs.**	**CREDIT**
B	1	223AGE100	ACADEMIC WRITING	3-0-0	3	-
	2	223AGE001	ADVANCED ENGINEERING MATERIALS	3-0-0	3	-
	3	223AGE002	FORENSIC ENGINEERING	3-0-0	3	-
	4	223AGE003	DATA SCIENCE FOR ENGINEERS	3-0-0	3	-
	5	223AGE004	DESIGN THINKING	3-0-0	3	-
	6	223AGE005	FUNCTIONAL PROGRAMMING IN HASKELL	3-0-0	3	-
	7	223AGE009	PRINCIPLES OF AUTOMATION	3-0-0	3	-
	8	223AGE010	REUSE AND RECYCLE TECHNOLOGY	3-0-0	3	-
	9	223AGE011	SYSTEM MODELING	3-0-0	3	-
	10	223AGE012	EXPERT SYSTEMS	3-0-0	3	-

223MEEXXX	MOOC COURSES	Category	L-T-P-C	YOI
		MOOC	0-0-0-2	2024

The MOOC course shall be considered only if it is conducted by the agencies namely AICTE/NPTEL/SWAYAM or NITTTR.

The MOOC course should have a minimum duration of 8 weeks and the content of the syllabus shall be enough for at least 40 hours of teaching. The course should have a proctored/offline end semester examination.

The students can do the MOOC according to their convenience, but shall complete it by third semester.

The list of MOOC courses will be provided by the concerned BoS if at least 70% of the course content match with the area/stream of study.

The course shall not be considered if its content has more than 50% of overlap with a core/elective course in the concerned discipline or with an open elective.

MOOC Course to be successfully completed before the commencement of fourth semester (starting from semester 1).

A credit of 2 will be awarded to all students whoever successfully completes the MOOC course as per the evaluation pattern of the respective agency conducting the MOOC.

223AGE100	ACADEMIC WRITING	Category	L-T-P-C	YOI
		Audit Course	3-0-0-0	2024

Preamble: Learning academic writing sharpens minds, teaches students how to communicate, and develops their thinking capacities and ability to understand others. Writing is thinking, and every student deserves to be a strong thinker. It can also make them think more carefully about what they write. Showing work to others can help to foster a better culture of learning and sharing among students. It also gives students a sense of how they are contributing to the body of work that makes up an academic subject.

Course Prerequisites: Nil.

Course Outcomes: The COs shown are only indicative. For each course, there can be 4 to 6 COs. After the completion of the course the student will be able to

CO 1	Understand the principles of scientific/ academic writing.
CO 2	Analyse the technique of scientific writing from the reader's perspective.
CO 3	Apply the concepts of setting expectations and laying the progression tracks
CO 4	Evaluate the merits of a title, abstract, introduction, conclusion and structuring of a research paper.
CO 5	Justify the need using a project proposal or a technical report.
CO 6	Prepare a review paper, an extended abstract and a project proposal.

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1		3	1				
CO 2		3	1				
CO 3		3	1			2	
CO 4		3	1				
CO 5		3	2	2		2	
CO 6	1	3	3	2		2	

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Apply	40%	**100**	**40**	**60**	**2.5** hours
Analyse	30%				
Evaluate	30%				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Course based task	:15 marks
Seminar/Quiz	:15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.)	:10 marks

End Semester Examination Pattern: 60 marks

The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum 1 question from each module of which student should answer any Five. Each question can carry 12 marks.

Syllabus and Course Plan (For 3 credit courses, the content can be for 40 hrs and for 2 credit courses, the content can be for 26 hrs. The audit course in third semester can have content for 30 hours).

SYLLABUS
MODULE I: (6 Hrs.)
Fundamentals of Academic writing from a reader's perspective: acronyms, synonyms, pronouns, disconnected phrases, background ghettos, abusive detailing, cryptic captions, long sentences: all that take their toll on readers' memory.
MODULE II: (6 Hrs.)
Fluid reading & reading energy consumption: setting expectations and laying Progression tracks; Reading energy consumption.
MODULE III: (6 Hrs.)
How to write the Title, abstract, introduction; Structure the writing with headings & subheadings.
MODULE IV: (6 Hrs.)
Visuals: Resources, Skills, and Methods; Conclusion; References; Bibliography; Grammar in technical writing.
MODULE V: (6 Hrs.)
Techniques of writing: An extended abstract, a project proposal, a research paper, a technical report.
Text book: 1. --
References: 1. SCIENTIFIC WRITING 2.0 A Reader and Writer's Guide: Jean-Luc Lebrun, World Scientific Publishing Co. Pte. Ltd., 2011 2. How to Write and Publish a Scientific Paper: Barbara Gastel and Robert A. Day, Greenwood publishers, 2016 3. Grammar, Punctuation, and Capitalisation; a handbook for technical writers and editors. www.sti.nasa.gov/publish/sp7084.pdf www.sti.nasa.gov/sp7084/contents.html 4. Everything You Wanted to Know About Making Tables and Figures. http://abacus.bates.edu/%7Eganderso/biology/resources/writing/HTWtableVigs.html.

223AGE001	ADVANCED ENGINEERING MATERIALS	Category	L-T-P-C	YOI
		Audit Course	3-0-0-0	2024

Preamble: This course is designed in a way to provide a general view on typically used advanced classes of engineering materials including metals, polymers, ceramics, and composites.

Course Prerequisites: Nil.

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

CO 1	Analyse the requirement and find appropriate solution for use of materials.
CO 2	Differentiate the properties of polymers, ceramics and composite materials.
CO 3	Recognize basic concepts and properties of functional materials.
CO 4	Comprehend smart and shape memory materials for various applications.
CO 5	Appraise materials used for high temperature, energy production and storage applications.

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3				3	3	
CO 2	3				3	3	
CO 3	3				3	3	
CO 4	3				3	3	
CO 5	3				3	3	

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Understand	60%	100	40	60	2.5 hours
Apply	20%				
Analyse	20%				
Evaluate	--				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Course based task :15 marks
Seminar/Quiz :15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.) :10 marks

End Semester Examination Pattern: 60 marks

The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum 1 question from each module of which student should answer any Five. Each question can carry 12 marks.

SYLLABUS
MODULE I: (5 Hrs.) Semester Exam Marks-20%
Requirements / needs of advanced materials. Classification of materials, Importance of materials selection, Criteria for selection of materials; motivation for selection, cost basis and service requirements. Relationship between materials selection and processing.

MODULE II: (7 Hrs.) Semester Exam Marks-20%
Classification of non-metallic materials. Polymer, Ceramics: Properties, processing and applications. Nano Composites - Polymer nanocomposites (PNCs), Processing and characterisation techniques – properties and potential applications.
MODULE III: (6 Hrs.) Semester Exam Marks-20%
Functionally graded materials (FGMs), Potential Applications of FGMs, classification of FGMs, processing techniques. Limitations of FGMs.
MODULE IV: (5 Hrs.) Semester Exam Marks-20%
Smart Materials: Introduction, smart material types - pyroelectric sensors, piezoelectric materials, electrostrictors and magnetostrictors, shape memory alloys – associated energy stimulus and response forms, applications.
MODULE V: (7 Hrs.) Semester Exam Marks-20%
High Temperature Materials: super alloys – main classes, high temperature properties of superalloys, applications. Energy Materials: materials for batteries.

Text book:

1. --

References:

1. DeGarmo et al, "Materials and Processes in Manufacturing", 10th Edition, Wiley, 2008.
2. R.E. Smallman and A.H.W. Ngan, Physical Metallurgy and Advanced Materials, Seventh Edition, Butterworth-Heinemann, 2007
3. Vijayamohanan K. Pillai and Meera Parthasarathy, "Functional Materials: A chemist's perspective", Universities Press Hyderabad (2012).
4. M.V. Gandhi, B.S. Thompson: Smart Materials and Structures, Chapman & Hall, 1992.
5. G. W. Meetham and M. H. Van de Voorde, Materials for High Temperature Engineering Applications (Engineering Materials) Springer; 1 edition (May 19, 2000)
6. Inderjit Chopra, Jayant Sirohi, "Smart Structures Theory", Cambridge University Press, 2013.

223AGE002	FORENSIC ENGINEERING	Category	L-T-P-C	YOI
		Audit Course	3-0-0-0	2024

Preamble: This course explores various aspects of Forensic Engineering and different methods, tools and procedures used by Engineers to investigate and analyze. The students will learn to develop their awareness in Forensic Engineering.

Course Prerequisites: Nil

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

CO 1	Identify the fundamental aspects of forensic Engineering.
CO 2	Apply forensic Engineering in Practical work flow and Investigation.
CO 3	Apply methods and analysis in Forensic Investigation.
CO 4	Develop practical strategies and standards of Investigation.
CO 5	Create an awareness in criminal cases and create Engineering expertise in court room on forensic Engineering.

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2	2	3	3	3	3	
CO 2	2	2	3	3	3	3	1
CO 3	3	3	3	3	3	3	1
CO 4	3	3	3	3	3	3	1
CO 5	3	3	3	3	3	3	

Assessment Pattern

Bloom's Category	Continuous Internal Evaluation	End Semester Examination	Mark distribution			
			Total Marks	CIE	ESE	ESE Duration
Apply	40%	60%	**100**	**40**	**60**	**2.5** hours
Analyse	40%	40%				
Evaluate	20%	--				
Create	--	--				

Continuous Internal Evaluation Pattern: 40 marks

Course based task :15 marks

Seminar/Quiz :15 marks

Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.) :10 marks

End Semester Examination Pattern: 60 marks

The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum 1 question from each module of which student should answer any Five. Each question can carry 12 marks.

SYLLABUS
MODULE I: Introduction to Forensic Engineering (6 Hrs.)
Forensic Engineering-Definition, Investigation Pyramid, Eyewitness Information, Role in Legal System Scientific Method-Applying scientific methods in Forensic Engineering-Engineer as expert Witness-Scientific methods and legal system Qualification of Forensic Engineer-Technical- Knowledge- Oral-written- Communication- other skills-Personality Characteristics Ethics and professional responsibilities.
MODULE II: Forensic Engineering Workflow & Investigation Methods (6 Hrs.)
Forensic Engineering Workflow-Team &planning-preliminary onsite investigation. Sampling-selection of sample-collection- packing-sealing of samples. Source and type of evidence - Paper documentation- digital documentation-electronic data. Physical Evidence-Collection of photograph-cataloguing -Recognizing the Evidence-organizing-Evidence Analysis -Reporting. Investigation Methods- Cause and Causal mechanism analysis-Time and event sequence-STEP method. Human Factors, Human errors -Analysis of Operative Instruction and working Procedures
MODULE III: Physical Product Failure & Analytical Methods (6 Hrs.)
Introduction to typical Forensic Engineering Tool box-NDT, Crack detection and human eye -Hardness testing- and Destructive testing Methods with case studies Indirect stress strain Analysis-Brittle lacquer technique, Contact Radiography-Metallography-EDAX method. Forensic Optical. Microscopy-Examination- Magnification-USB Microscopy -Wifi Enabled microscopy -Reflected microscopy. Novel Tools and System -Contour Method-Flash Thermography-Thermographic signal reconstruction (TSR)-Electromagnetically induced acoustic Emission (EMAE)-Pulsed Eddy Current (PEA)-Theory only.
MODULE IV: Cyber Forensic, Civil ,Electrical Accidents & Standards (6 Hrs.)
Basics of Digital & Cyber forensics: Technical concepts; labs and tools; collecting evidence Operating System Forensic basics with - Windows, Linux -Mobile Forensic-Anti forensics-Malware- Web attack forensics with Email Crimes-Cyber Laws. Different types of Forensic accident investigations- Civil Engineering- Structural- Road accidents -Fire accidents - Water related accidents- Electrical accidents and Investigation methods. Protocol for forensic Investigations-Standard guides-scope significance - use -procedures- reports. Standards – ASTM standards -FMV Standards - SAE Standards -Relevant Standards -NFPA Standards -International Standards.
MODULE V: Engineer in the Court room& Criminal Cases (6 Hrs.)
Role of an Engineering Expert-Report-pre trial meetings-Alternative dispute resolution-Single joint expert. Engineer in the court room. Criminal Cases-Introduction- Counterfeit coins-fraudulent road accidents-Fraudulent Insurance claims. Cyber Crimes and Cases- SIM Swapping -ATM Cloning-Microsoft Internal Spam- Intellectual property cases.
Text book: 1. --
References: 1. Colin R Gagg, Forensic EngineeringThe Art &Craft of a failure detective , Taylor & Francis Publishing, 2020 2. Luca Fiorentini ,Luca Marmo Principles of Forensic Engineering Applied to Industrial Accidents , Wiley, 2019 3. Harold Franck, Darren Franck , Forensic Engineering Fundamentals ,Taylor & Francis publishing 2013 4. Randall K Noon , Forensic Engineering Investigation, CRC press limited , 2001 5. Stephen E Petty , Forensic Engineering: Damage assessment for residential and commercial structures CRC press 2nd edition , 2017 6. Joshua B Kardon , Guideliness for forensic Engineering practice , ASCE, 2012

7. Richard W. Mclay and Robert N. Anderson, Engineering standards for forensic Applications , Academic Press; 1st edition 2018
8. Max M Houck ,Forensic Engineering (Advanced forensic Science), Academic press 1st edition 2017
9. Niranjan Reddy - Practical Cyber Forensics. An Incident-based Approach to Forensic Investigations-Apress (2019)
10. Peter Rhys Lewis, Ken Reynolds, Colin Gagg - Forensic Materials Engineering Case Studies- CRC Press (2003) (1)

223AGE003	DATA SCIENCE FOR ENGINEERS	Category	L-T-P-C	YOI
		Audit Course	3-0-0-0	2024

Preamble: This course covers essentials of statistics and Linear Algebra and how to prepare the data before processing in real time applications. The students will be able to handle missing data and detection of any outliers available in the dataset. This course explores data science, Python libraries and it also covers the introduction to machine learning for engineers.

Course Prerequisites: Nil

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

CO 1	Study Data Science Concepts and statistics.
CO 2	Demonstrate Understanding of Mathematical Foundations needed for Data Science.
CO 3	Understand Exploratory analysis and Data Visualization and Preprocessing on given dataset.
CO 4	Implement Models such as Naive Bayes, K-Nearest Neighbors, Linear and Logistic Regression.
CO 5	Build real time data science applications and test use cases.

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2		2			2	
CO 2	2		2	1		2	
CO 3	2		2	2	2	2	
CO 4	2		2	2	3	2	
CO 5	2		2	3	3	3	2

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Understand	50%	100	40	60	2.5 hours
Apply	30%				
Analyse	20%				
Evaluate	--				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Course based task :15 marks
Seminar/Quiz :15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.) :10 marks

End Semester Examination Pattern: 60 marks

The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum 1 question from each module of which student should answer any Five. Each question can carry 12 marks.

SYLLABUS
MODULE I: Statistics for Data science (6 Hrs.) Semester Exam Marks-20%
Probability: Basic concepts of probability, conditional probability, total probability, independent events, Bayes' theorem, random variable, Population, Sample, Population Mean, Sample Mean, Population Distribution, Sample Distribution and sampling Distribution, Mean, Mode, Median, Range, Measure of Dispersion, Variance, Standard Deviation, Gaussian/Normal Distribution, covariance, correlation.
MODULE II: Linear Algebra (6 Hrs.) Semester Exam Marks-20%
Vectors and their properties, Sum and difference of Vectors, distance between Vectors, Matrices, Inverse of Matrix, Determinant of Matrix, Trace of a Matrix, Dot Product, Eigen Values, Eigen Vectors, Single Value Decomposition
MODULE III: Hypothesis Testing (6 Hrs.) Semester Exam Marks-20%
Understanding Hypothesis Testing, Null and Alternate Hypothesis, Non-directional Hypothesis, Directional Hypothesis Critical Value Method, P-Value Method, Types of Errors-Type1 Error, Type2 Error, Types of Hypothesis Test Z Test, Chi-Square
MODULE IV: Exploratory Data Analysis (6 Hrs.) Semester Exam Marks-20%
Data Collection –Public and Private Data, Data Cleaning-Fixing Rows and Columns, Missing Values, Standardizing values, invalid values, filtering data, Data-Integration, Data-Reduction, Data Transformation
MODULE V: Machine Learning & Python for Data Science (6 Hrs.) Semester Exam Marks-20%
Python Data structures-List, Tuple, Set, Dictionary, Pandas, Numpy, Scipy, Matplotlib, Machine Learning- Supervised Machine Learning, Unsupervised Machine Learning,Regression, Classification, Naïve-Bayes.
Text book: 1. --
References: 1. Python Data Science Handbook. Essential Tools for Working with Data, Author(s): Jake VanderPlas, Publisher: O'Reilly Media, Year: 2016 2. Practical Statistics for Data Scientists: 50 Essential Concepts, Author(s): Peter Bruce, Andrew Bruce, Publisher: O'Reilly Media, Year: 2017 3. Practical Linear Algebra for Data Science, by Mike X Cohen, Released September 2022, Publisher(s): O'Reilly Media, Inc. 4. Data Science from Scratch 'by Joel Grus, Released, April 2015, Publisher(s): O'Reilly Media, Inc. 5. Hands-On Exploratory Data Analysis with Python, by Suresh Kumar Mukhiya, Usman Ahmed, Released March 2020, Publisher(s): Packt Publishing

223AGE004	DESIGN THINKING	Category	L-T-P-C	YOI
		Audit Course	3-0-0-0	2024

Preamble: This course offers an introductory exploration of fundamental engineering concepts and techniques, the design process, analytical thinking and creativity, as well as the fundamentals and development of engineering drawings, along with their application in engineering problems.

Course Prerequisites: Nil

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

CO 1	Identify and frame design challenges effectively.
CO 2	Generate creative ideas through brainstorming and ideation
CO 3	Iterate on designs based on user insights
CO 4	Apply Design Thinking to real-world problems and projects.

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1				2		2	2
CO 2	2		2	2			2
CO 3		2		2		2	2
CO 4	2		2	3	2		2

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Apply	40%	100	40	60	2.5 hours
Analyse	30%				
Evaluate	30%				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Course based task :15 marks
Seminar/Quiz :15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.) :10 marks

End Semester Examination Pattern: 60 marks

The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum 1 question from each module of which student should answer any Five. Each question can carry 12 marks.

Syllabus and CorsePlan (For 3credit courses, thec ontent can be for 40 hrs and for2credit courses, the content can be for 26 hrs. The audit course in third semester can have content for 30hours).

SYLLABUS
MODULE I
Design process: Traditional design, Design Thinking Approach, Introduction to Design Thinking, History and evolution of Design Thinking, Role of design thinking in the human-centred design process. Design space, Design Thinking in a Team Environment, Team formation.
MODULE II
Design Thinking Stages: Empathize, Define, Ideate, Prototype and Test. The importance of empathy, Building a user-centred mindset. Problem statement formulation, User needs and pain points, establishing target specifications, Setting the final specifications.
MODULE III
Generating Ideas, Brainstorming techniques, Application of Aesthetics and Ergonomics in Design. Bio-mimicry, Conceptualization, Visual thinking, Drawing/Sketching, Presenting ideas.
MODULE IV
Use of prototyping, Types of prototypes, Rapid prototyping techniques, User testing and feedback collection, Iterative prototyping, testing to gauge risk and market interest.
MODULE V
Entrepreneurship/business ideas, Patents and Intellectual Property, Agility in design, Ethical considerations in design. Overcoming common implementation challenges.

Text book:

1. --

References:

1. Christoph Meinel, Larry Leifer and Hasso Plattner- “Design Thinking: Understand – Improve – Apply”, Springer Berlin, Heidelberg, 2011.
2. Thomas Lockwood and Edgar Papke – “Design Thinking: Integrating Innovation, Customer Experience, and Brand Value", Allworth Press, 2009.
3. Pavan Soni – “Design Your Thinking”, Penguin Random House India Private Limited, 2020.
4. Andrew Pressman- “Design Thinking : A Guide to Creative Problem Solving for Everyone”, Taylor & Francis, 2018.
5. N Siva Prasad, “Design Thinking Techniques an Approaches” Ane Books Pvt. Ltd.,2023

223AGE005	FUNCTIONAL PROGRAMMING IN HASKELL	Category	L-T-P-C	YOI
		Audit Course	3-0-0-0	2024

Preamble: This course introduces a functional programming approach in problem solving. Salient features of functional programming like recursion, pattern matching, higher order functions etc. and the implementation in Haskell are discussed.

Course Prerequisites: Nil

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

CO 1	Understand the functional programming paradigm which is based on the mathematics of lambda calculus.
CO 2	Develop Haskell programs using functions, guards and recursive functions
CO 3	Apply the concept of tuples, lists and strings in Haskell programming.
CO 4	Apply the concept of algebraic data types, abstract data types, modules, recursive data types and user defined data types in Haskell programming.
CO 5	Develop Haskell programs with files for reading input and storing output.

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1					3		
CO 2	2			2	3		
CO 3	2			2	3		
CO 4	2			2	3		
CO 5	2			2	3		

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Apply	40%	100	40	60	2.5 hours
Analyse	40%				
Evaluate	20%				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Course based task (Project/Assignments/Simulations/Case studies) :15 marks
Seminar/Quiz :15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.) :10 marks

End Semester Examination Pattern: 60 marks

The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum 1 question from each module of which student should answer any Five. Each question can carry 12 marks.

Syllabus and Corse Plan (For 3 credit courses, the content can be for 40 hrs and for 2 credit courses, the content can be for 26 hrs. The audit course in third semester can have content for 30 hours).

SYLLABUS
MODULE I Introduction to Functional Programming (5 Hrs.)

Introduction to Functional Programming: Programming language paradigms, imperative style programming, comparison of programming paradigms.
Functional programming, Functions - Mathematical concepts and terminology, Lambda calculus, Function definitions, programs as functions, Functional programming Languages. Haskell basics, GHCi interpreter.

MODULE II: Programming in Haskell (6 Hrs.)

Programming in Haskell: Expressions and evaluation, Lazy evaluation, let expressions, scopes.
Basic data types in Haskell, operators, infix operators, associativity and precedence, Arithmetic functions.
Types, definitions, currying and uncurrying, type abstraction.
Function definitions, pattern matching, guards, anonymous functions, higher order functions. Recursion, Programming exercises.

MODULE III: Data types: tuples and lists (7 Hrs.)

Data types: tuples and lists: Tuples , Lists: building lists, decomposing lists, functions on lists, built- in functions on lists, primitive and general recursion over lists, infinite lists.
Strings: functions on strings.
Polymorphism and overloading, conditional polymorphism.

MODULE IV: User defined data types (6 Hrs.)

Type classes, Algebraic data types, Modules, Recursive data types.
User defined data types, Records, Stacks, Queues, Binary trees, Constructors, Destructors.

MODULE V: Programming with actions (6 Hrs.)

Functor, Applicative functor, Monad
Programming with actions: Functions vs actions, Basics of input / output, the do notation, interacting with the command line and lazy I/O, File I/O.

Text book:

1. --

References:

1. Richard Bird, “Introduction to functional programming using Haskell', second edition, Prentice hall series in computer science
2. Bryan O'Sullivan, Don Stewart, and John Goerzen, “Real World Haskell”
3. Richard Bird, “Thinking Functionally with Haskell”, Cambridge University Press, 2014
4. Simon Thompson, “Haskell: The Craft of Functional Programming”, Addison-Wesley, 3rd Edition, 2011
5. H. Conrad Cunningham, “Notes on Functional Programming with Haskell”, 2014
6. Graham Hutton, “Programming in Haskell”, Cambridge University Press, 2nd Edition, 2016
7. Alejandro Serrano Mena, “Practical Haskell: A Real-World Guide to Functional Programming”, 3rd Edition, Apress, 2022
8. Miran Lipovaca, “Learn You a Haskell for Great Good!: A Beginner's Guide”, No Starch Press, 2011

223AGE009	PRINCIPLES OF AUTOMATION	Category	L-T-P-C	YOI
		Audit Course	3-0-0-0	2024

Preamble: This course deals in detail with the various aspects of automation such as sensors, actuators, controllers, mechanical and electrical elements and their integration for automating new and existing manufacturing and process industries and applications. This course will be beneficial to students in designing automation schemes for industries and to design automated systems.

Course Prerequisites: Nil

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

CO 1	Explain the fundamentals of sensor systems and to choose a suitable sensor system for the given application based on the evaluation of the constraints.
CO 2	Explain the fundamentals of signal conditions and to design a suitable signal conditioning scheme for given application.
CO 3	Describe the characteristics of various actuator systems and to decide the right type of actuator for the given application.
CO 4	Describe the importance of an industrial robot and fundamentals of numerical control in automation.
CO 5	Explain the fundamentals of controllers used in industrial automation and to construct simple automation schemes by ladder logic programs.

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2		2	2	2		
CO 2	2		2	2	2		
CO 3	2		2	2	2		
CO 4	2		2	2	2		
CO 5	2		2				

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Understand	70%	100	40	60	2.5 hours
Apply	30%				
Analyse	--				
Evaluate	--				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Course based task (Project/Assignments/Simulations/Case studies) :15 marks
Seminar/Quiz :15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.) :10 marks

End Semester Examination Pattern: 60 marks

The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum 1 question from each module of which student should answer any Five. Each question can carry 12 marks.

SYLLABUS

MODULE I: Introduction to Industrial Automation

Basic Elements of an Automated System, Levels of Automation. Hardware components for Automation: Sensors, classification, Static and dynamic behaviour of sensors. Basic working principle of different sensors: Proximity sensors, Temperature sensors, flow sensors, Pressure sensors, Force sensors. Position sensors

MODULE II: Signal conditioning

Need for signal conditioning, Types of signal conditioning. Signal conditioning using operational amplifier-Amplifier (Inverting and Non-inverting) and Filter circuits (Basic concepts). Design of first order low pass filter. Signal conditioning for data acquisition systems, anti-aliasing filters, Analog–Digital Conversions, Analog-to-Digital Converters (ADC)- Steps in analog-to-digital conversion, Successive Approximation Method, Digital-to-Analog Converters (DAC)- Steps in digital to analog conversion, Zero-order & first order data hold circuits.

MODULE III: Actuators

Types of actuators- mechanical, electrical, pneumatic and hydraulic actuators. (Basic working principle) Mechanical systems for motion conversion, transmission systems. Solenoids, Electric and stepper motors control.

MODULE IV: Robotics and Automated Manufacturing Systems

Robot Anatomy and Related Attributes: Joints and Links, Common Robot Configurations, Joint Drive Systems, Sensors in Robotics (Basic concepts). Robot Control Systems, Applications of Industrial Robots- Material handling Fundamentals of Numerical control (NC) Technology.

MODULE V: Discrete Control and Programmable Logic Controllers

Discrete Process Control: Logic and Sequence control. Ladder Logic Diagrams, Programmable Logic Controllers: Components of the PLC, PLC Operating Cycle, Programming the PLC (Basic concepts only). Introduction to Distributed control system (DCS) and Supervisory Control and Data Acquisition Systems (SCADA)

Text book:

1. --

References:

1. Mikell Groover, Automation, Production Systems, and Computer-Integrated Manufacturing, 5th Edition, Pearson, 2019.
2. Yoram Koren, "Computer Control of Manufacturing Systems",TataMcGraw Hill Edition2005.
3. S. R. Deb; Sankha Deb. Robotics Technology and Flexible Automation, Second Edition McGraw-Hill Education: New York, 2010.
4. W. Bolton, "Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering" - PrenticeHall- 2013 - 5th Edition.
5. Doebelin, E.O. and Manic, D.N., "Measurement Systems: Applications and Design", 7th Edition, McGraw Hill, 2019.
6. Krishna Kant, Computer Based Industrial Control-, EEE-PHI,2nd edition,2010.
7. Nathan Ida, Sensors, Actuators, and Their Interfaces- A multidisciplinary introduction, 2nd Edition, IET Digital Library, 2020.
8. Salivahanan, S., and VS Kanchana Bhaaskaran. Linear integrated circuits. McGraw- Hill Education, 2nd edition, 2014.
9. Petruzella, Frank D. Programmable logic controllers. Tata McGraw-Hill Education, 2005
10. Chapman and Hall, "Standard Handbook of Industrial Automation", Onsidine DM C & Onsidine GDC", NJ, 1986.

223AGE010	REUSE AND RECYCLE TECHNOLOGY	Category	L-T-P-C	YOI
		Audit Course	3-0-0-0	2024

Preamble: "Reuse and Recycle Technology" typically focuses on sustainable practices and technologies aimed at reducing waste, conserving resources, and promoting environmental responsibility.

Course Prerequisites: Nil.

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

CO 1	Explain the principles and technologies behind waste reduction, resource conservation, and sustainable practices.
CO 2	Describe and Analyze waste generation and management.
CO 3	Apply the knowledge of various reuse strategies and their application in different industries and Analyze various recycling technologies.
CO 4	Appraise the methods of E-waste management and Eco-friendly packaging.
CO 5	Comprehend Environmental Regulations and Policies, Understand the importance of environmental regulations and policies in addressing environmental challenges.

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1			3				
CO 2				3			
CO 3				3			
CO 4					3		
CO 5			3				

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Understand	60%	100	40	60	2.5 hours
Apply	20%				
Analyse	20%				
Evaluate	--				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Course based task (Project/Assignments/Simulations/Case studies) :15 marks
Seminar/Quiz :15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.) :10 marks

End Semester Examination Pattern: 60 marks

The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum 1 question from each module of which student should answer any Five. Each question can carry 12 marks.

SYLLABUS
MODULE I: (6 Hrs.) Semester Exam Marks: 20 %
Introduction to Sustainability, Understanding sustainability and its importance, The three pillars of sustainability: Environmental, Social, and Economic. Biodiversity conservation, Climate change and mitigation Sustainable resource management.
MODULE II: (6 Hrs.) Semester Exam Marks:20 %
Waste Management, Definition and classification of waste, Waste Generation and Composition, Waste Collection and Transportation, Waste Segregation and Sorting. Waste Disposal Methods Historical perspectives on waste management, The three Rs: Reduce, Reuse, and Recycle.
MODULE III: (6 Hrs.) Semester Exam Marks:20 %
Recycling and Reuse: Importance of reuse, Application of reuse in various industries, Challenges and opportunities in reuse, Overview of recycling technologies, Circular economy, Sorting and processing of recyclable materials, Advanced recycling methods. Emerging technologies in recycling.
MODULE IV: (6 Hrs.) Semester Exam Marks:20 %
E-waste Recycling, Challenges and environmental impact of electronic waste, E-waste recycling methods and regulations, Sustainable electronics design, Sustainable Packaging, Packaging materials and their environmental impact, Eco-friendly packaging alternatives, Packaging design for sustainability.
MODULE V: (6 Hrs.) Semester Exam Marks:20 %
Environmental Regulations and Policies, Understand the importance of environmental regulations and policies in addressing environmental challenges, National and international waste and recycling regulations, Compliance and enforcement, Industry standards and certifications.
Text book: 1. --
References: 1. Sustainable Engineering: Concepts, Design and Case Studies, David T. Allen, Pearson Publication. 2. A Comprehensive Book on Solid Waste Management with Application, Dr. H.S. Bhatia , Misha Books, 2019 3. "Cradle to Cradle: Remaking the Way We Make Things" by William McDonough and Michael Braungart. 4. "Recycling of Plastic Materials" edited by Vijay Kumar Thakur 5. E-waste: Implications, Regulations and Management in India and Current Global Best Practices, Rakesh Johri, TERI 6. "Sustainable Packaging”, Subramanian Senthilkannan Muthu , Springer Nature. 7. Indian Environmental Law: Key Concepts and Principles " Orient Black swan Private Limited, New Delhi.

223AGE011	SYSTEM MODELLING	Category	L-T-P-C	YOI
		Audit Course	3-0-0-0	2024

Preamble: Study of this course provides the learners a clear understanding of fundamental concepts in simulation and modelling. This course covers the different statistical models, importance of data collection and various types of simulations. The course helps the learners to find varied applications in engineering, medicine and bio-technology.

Course Prerequisites: Nil.

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

CO 1	Analyse the requirement and find appropriate tool for simulation.
CO 2	Differentiate the different statistical models.
CO 3	Discuss the different techniques for generating random numbers.
CO 4	Analyse the different methods for selecting the different input models.
CO 5	Discuss the different measures of performance and their estimation.

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	2		1	1	2		
CO 2	2		1	1	1		
CO 3	1						
CO 4	1		1	1			
CO 5	2		1	1	1		

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Understand	60%	100	40	60	2.5 hours
Apply	20%				
Analyse	20%				
Evaluate	--				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Course based task (Project/Assignments/Simulations/Case studies) :15 marks
Seminar/Quiz :15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.) :10 marks

End Semester Examination Pattern: 60 marks

The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum 1 question from each module of which student should answer any Five. Each question can carry 12 marks.

SYLLABUS
MODULE I: (6 Hrs.) Semester Exam Marks: 20 %
When simulation is the appropriate tool. Advantages and disadvantages of Simulation; Areas of application, Systems and system environment; Components of a system; Discrete and continuous systems, Model of a system; Types of Models, Discrete-Event System Simulation, Steps of a simulation study.
MODULE II: (6 Hrs.) Semester Exam Marks: 20 %
Review of terminology and concepts, Useful statistical models, Discrete distributions. Continuous distributions, Poisson process, Empirical distributions. (basic idea only)
MODULE III: (6 Hrs.) Semester Exam Marks: 20 %
Properties of random numbers; Generation of pseudo- random numbers, Techniques for generating random numbers, Tests for Random Numbers
MODULE IV: (6 Hrs.) Semester Exam Marks: 20 %
Data Collection; Identifying the distribution with data, Parameter estimation, Goodness of Fit Tests, Fitting a non-stationary Poisson process, Selecting input models without data, Multivariate and Time-Series input models.
MODULE V: (6 Hrs.) Semester Exam Marks: 20 %
Measures of performance and their estimation, Output analysis for terminating simulations, Output analysis for steady-state simulations, Verification, calibration and validation.
Text book: 1. Jerry Banks, John S. Carson II, Barry L. Nelson, David M. Nicol: Discrete-Event System Simulation, 5th Edition, Pearson Education, 2010.
References: 1. Lawrence M. Leemis, Stephen K. Park: Discrete – Event Simulation: A First Course, Pearson Education, 2006. 2. Averill M. Law: Simulation Modeling and Analysis, 4 th Edition, Tata McGraw-Hill, 2007 3. System Modelling and Response by Ernest O. Doebelin 4. Averill M Law, “Simulation Modeling and Analysis”,McGraw-Hill Inc,2007 Geoffrey Gorden, “System Simulation”,Prentice Hall of India,1992.

223AGE012	EXPERT SYSTEMS	Category	L-T-P-C	YOI
		Audit Course	3-0-0-0	2024

Preamble: The course aims to provide an understanding of the basic concepts of Artificial Intelligence (AI) and Expert Systems. The course also covers the knowledge representation in expert systems, classes of expert systems, applications of expert systems.

Course Prerequisites: Nil.

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

CO 1	Explain the concepts of Artificial Intelligence and different ways of knowledge representations.
CO 2	Explain the components of expert systems, development stages of expert systems and tools available for expert system design.
CO 3	Apply the concept of knowledge representation in expert systems
CO 4	Differentiate the classes of expert systems and examine properties of existing systems

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	1		2	1	2	2	
CO 2	1		1	3	2	2	
CO 3	1		1	2	2	2	
CO 4	2		2	2	3	2	

Assessment Pattern

Bloom's Category	End Semester Examination	Mark distribution			
		Total Marks	CIE	ESE	ESE Duration
Understand	60%	100	40	60	2.5 hours
Apply	20%				
Analyse	20%				
Evaluate	--				
Create	--				

Continuous Internal Evaluation Pattern: 40 marks

Course based task (Project/Assignments/Simulations/Case studies) :15 marks
Seminar/Quiz :15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus.) :10 marks

End Semester Examination Pattern: 60 marks

The examination will be conducted by the respective College. The examination will be for 150 minutes and will contain 7 questions, with minimum 1 question from each module of which student should answer any Five. Each question can carry 12 marks.

SYLLABUS
MODULE I: (6 Hrs.) Semester Exam Marks: 20 %
Overview of Artificial Intelligence (AI): Definition & Importance of AI. Knowledge general concepts: Definition and Importance of knowledge, Knowledge-Based Systems, Knowledge organization, Knowledge Manipulation and acquisition. Knowledge Representation: Introduction, Syntax and Semantics- Propositional logic and predicate logic.

MODULE II: (6 Hrs.) Semester Exam Marks: 20 %
Basic concepts of expert systems-Introduction to expert systems, Components of expert systems. Features of Expert System, Stages in the development of expert system, Types of tools available for expert system design.
MODULE III: (6 Hrs.) Semester Exam Marks: 20 %
Knowledge representation in expert systems: Structured Knowledge representation: Graphs, Frames and related structures, Associative networks, Conceptual dependencies, Examples of structured knowledge representation.
MODULE IV: (7 Hrs.) Semester Exam Marks:20 %
Classes of expert systems: Rule-based expert systems, Example- MYCIN, Frame-based expert system, terminologies, IF-THEN structure. Fuzzy and Neural network based expert systems (basic concepts).
MODULE V: (5 Hrs.) Semester Exam Marks: 20 %
Currents trends in expert systems, Advantages and limitations of expert systems, Applications of expert systems.
Text book: 1. --
References: 1. E. Rich & K. Knight - Artificial Intelligence, 2/e, TMH, New Delhi, 2005. 2. P.H. Winston - Artificial Intelligence, 3/e, Pearson Edition, New Delhi, 2006. 3. D.W. Rolston - Principles of AI & Expert System Development, TMH, New Delhi 4. Kevin Night and Elaine Rich, Nair B., “Artificial Intelligence (SIE) “, McGraw Hill – 2010 5. Dan W Patterson, ‘Introduction to Artificial intelligence and Expert systems’, Prentice Hall of India Pvt. Ltd,2007 6. Russel (Stuart), ‘Artificial Intelligence- Modern approach, Pearson Education series in AI’, 3rd Edition, 2009. 7. I. Gupta, G. Nagpal · Artificial Intelligence and Expert Systems, Mercury Learning and Information -2020

223IEE100	INTERNSHIP	Category	L-T-P-C	YOI
		Internship	0-0-0-3	2024

A student shall opt for carrying out the Internship at an Industry/Research Organization or at another institute of higher learning and repute (Academia). The organization for Internship shall be selected/decided by the students on their own with prior approval from the faculty advisor/respective PG Programme Coordinator/Guide/Supervisor. Every student shall be assigned an internship Supervisor/Guide at the beginning of the Internship. The training shall be related to their specialisation after the second semester for a minimum duration of six to eight weeks. On completion of the course, the student is expected to be able to develop skills in facing and solving the problems experiencing in the related field.

Objectives

- Exposure to the industrial environment, which cannot be simulated in the classroom and hence creating competent professionals for the industry.
- Provide possible opportunities to learn understand and sharpen the real time technical / managerial skills required at the job.
- Exposure to the current technological developments relevant to the subject area of training.
- Create conducive conditions with quest for knowledge and its applicability on the job.
- Understand the social, environmental, economic and administrative considerations that influence the working environment.
- Expose students to the engineer's responsibilities and ethics.

Benefits of Internship

Benefits to Students

- An opportunity to get hired by the Industry/ organization.
- Practical experience in an organizational setting & Industry environment.
- Excellent opportunity to see how the theoretical aspects learned in classes are integrated into the practical world. On-floor experience provides much more professional experience which is often worth more than classroom teaching.
- Helps them decide if the industry and the profession is the best career option to pursue.
- Opportunity to learn new skills and supplement knowledge.
- Opportunity to practice communication and teamwork skills.
- Opportunity to learn strategies like time management, multi-tasking etc. in an industrial setup.
- Makes a valuable addition to their resume.
- Enhances their candidacy for higher education/placement.
- Creating network and social circle and developing relationships with industry people.
- Provides opportunity to evaluate the organization before committing to a full-time position.

Benefits to the Institute

- Build industry academia relations.
- Makes the placement process easier.
- Improve institutional credibility & branding.
- Helps in retention of the students.
- Curriculum revision can be made based on feedback from Industry/ students.
- Improvement in teaching learning process.

Benefits to the Industry

- Availability of ready to contribute candidates for employment.
- Year-round source of highly motivated pre-professionals.
- Students bring new perspectives to problem solving.
- Visibility of the organization is increased on campus.
- Quality candidate's availability for temporary or seasonal positions and projects.
- Freedom for industrial staff to pursue more creative projects.
- Availability of flexible, cost-effective workforce not requiring a long-term employer commitment.
- Proven, cost-effective way to recruit and evaluate potential employees.
- Enhancement of employer's image in the community by contributing to the educational enterprise.

Types of Internships

- Industry Internship with/without Stipend
- Govt / PSU Internship (BARC/Railway/ISRO etc.)
- Internship with prominent education/research Institutes
- Internship with Incubation centres /Start-ups

Guidelines

- All the students need to go for internship for minimum duration of 6 to 8 weeks.
- Students can take mini projects, assignments, case studies by discussing it with concerned authority from industry and can work on it during internship.
- All students should compulsorily follow the rules and regulations as laid by industry.
- Every student should take prior permissions from concerned industrial authority if they want to use any drawings, photographs or any other document from industry.
- Student should follow all ethical practices and SOP of industry.
- Students have to take necessary health and safety precautions as laid by the industry.
- Student should contact his /her Guide/Supervisor from college on weekly basis to communicate the progress.
- Each student has to maintain a diary/log book
- After completion of internship, students are required to submit
    - ✓ Report of work done
    - ✓ Internship certificate copy
    - ✓ Feedback from employer / internship mentor
    - ✓ Stipend proof (in case of paid internship).

Total Marks 100: The marks awarded for the Internship will be on the basis of (i) Evaluation done by the Industry (ii) Students diary (iii) Internship Report and (iv) Comprehensive Viva Voce.

Continuous Internal Evaluation: 50 marks

Student's diary - 25 Marks

Evaluation done by the industry - 25 Marks

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 training 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 training diary should be signed after every day by the supervisor/ in charge of the section where the student has been working. The diary should also be shown to the Faculty Mentor visiting the industry from time to time and got ratified on the day of his visit. Student's diary will be evaluated on the basis of the following criteria:

- ✓ Regularity in maintenance of the diary
- ✓ Adequacy & quality of information recorded
- ✓ Drawings, design, sketches and data recorded
- ✓ Thought process and recording techniques used
- ✓ Organization of the information.

The format of student's diary

Name of the Organization/Section:

Name and Address of the Section Head:

Name and Address of the Supervisor:

Name and address of the student:

Internship Duration: From .... To ....

Brief description about the nature of internship:

Day	Brief write up about the Activities carried out: Such as design, sketches, result observed, issues identified, data recorded, etc.
1	
2	
3	

Signature of Industry Supervisor   *Signature of Section Head/HR Manager*

Office Seal

Attendance Sheet

Name of the Organization/Section:

Name and Address of the Section Head:

Name and Address of the Supervisor:

Name and address of the student:

Internship Duration: From .... To ....

Month & Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	...
Month & Year																					
Month & Year																					

Signature of Industry Supervisor *Signature of Section Head/HR Manager*

Office Seal

Note:

- Student's Diary shall be submitted by the students along with attendance record and an evaluation sheet duly signed and stamped by the industry to the Institute immediately after the completion of the training.
- Attendance Sheet should remain affixed in daily training diary. Do not remove or tear it off.
- Student shall sign in the attendance column. Do not mark 'P'.
- Holidays should be marked in red ink in the attendance column. Absent should be marked as 'A' in red ink.

Evaluation done by the Industry (Marks 25)

Format for Supervisor Evaluation of Intern

Student Name :____________________Date:______________________________________

Supervisor Name :_________________Designation:_________________________________

Company/Organization :____

Internship Address: ____

Dates of Internship: From__________________________To __________________________

Please evaluate intern by indicating the frequency with which you observed the following parameters:

Marks / **Parameters**	Needs improvement (0 – 0.25 mark)	Satisfactory (0.25 – 0.50 mark)	Good (0.75 mark)	Excellent (1 mark)
Behavior				
Performs in a dependable Manner				
Cooperates with coworkers and supervisor				
Shows interest in work				
Learns quickly				
Shows initiative				
Produces high quality work				
Accepts responsibility				
Accepts criticism				
Demonstrates organizational skills				
Uses technical knowledge and expertise				
Shows good judgment				
Demonstrates creativity/originality				
Analyzes problems effectively				
Is self-reliant				
Communicates well				
Writes effectively				
Has a professional attitude				
Gives a professional appearance				
Is punctual				
Uses time effectively				

Overall performance of student Intern (Tick one) :Needs improvement (0 - 0.50 mark) / Satisfactory (0.50 – 1.0 mark) / Good (1.5 mark) / Excellent (2.0 mark)

Additional comments, if any (2 marks) :

Signature of Industry Supervisor *Signature of Section Head/HR Manager*

Office Seal

End Semester Evaluation (External Evaluation): 50 Marks

Internship Report	-	25 Marks
Viva Voce	-	25 Marks

Internship Report: After completion of the internship, the student should prepare a comprehensive report to indicate what he has observed and learnt in the training period and should be submitted to the faculty Supervisor. The student may contact Industrial Supervisor/ Faculty Mentor for assigning special topics and problems and should prepare the final report on the assigned topics. Daily diary will also help to a great extent in writing the industrial report since much of the information has already been incorporated by the student into the daily diary. The training report should be signed by the Internship Supervisor, Programme Coordinator and Faculty Mentor.

The Internship report (25 Marks) will be evaluated on the basis of following criteria:

- ✓ Originality
- ✓ Adequacy and purposeful write-up
- ✓ Organization, format, drawings, sketches, style, language etc.
- ✓ Variety and relevance of learning experience
- ✓ Practical applications, relationships with basic theory and concepts taught in the course

Viva Voce (25 Marks) will be done by a committee comprising Faculty Supervisor, PG Programme Coordinator and an external expert (from Industry or research/academic Institute). This committee will be evaluating the internship report also.

223PEE001/ 223PEE100	RESEARCH PROJECT/ DISSERTATION	Category	L-T-P-C	YOI
		Project Work	0-0-17-11	2024

Research Project (223PEE001): Students choosing track 2 shall carry out the research project in their parent Institution only under the guidance of a supervisor assigned by the DLAC.

Dissertation (223PEE100): All categories of students in track 1 are to carry out the dissertation in the Institute they are studying or can work either in any CSIR/Industrial R&D organization/any other reputed Institute which have facilities for dissertation work in the area proposed.

Mark Distribution:

Phase 1: Total marks: 100, only CIA

223PEE100	DISSERTATION PHASE I	Category	L-T-P-C	YOI
		Project Work	0-0-17-11	2024

Course Objectives: Dissertation is aimed to bridge the gap between theoretical knowledge and practical application, fostering a well-rounded skill set that prepares students for success in their future engineering careers. Engineering projects often simulate real-world engineering scenarios. This exposure allows students to become familiar with industry practices, standards, and expectations and preparing them for the challenges they might face in their future careers. Depending on the nature of the project, students may acquire practical skills related to specific tools, software, or equipment. This hands-on experience can be highly beneficial when transitioning to a professional engineering role.

Dissertation Phase I can help to identify the problem based on the area of interest through proper literature survey and to foster innovation in design of products, processes or systems based on the identified problem. perform feasibility study by creative thinking and requirement analysis in finding viable solutions to engineering problems.

All categories of students in track 1 are to carry out the dissertation in the Institute they are studying or in any CSIR/Industrial/ R&D organization/any other reputed institute which have facilities for dissertation work in the area proposed.

Course Prerequisites: Nil

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

CO 1	Identify and define a relevant and significant problem or challenge in the relevant field.
CO 2	Formulate research methodologies for the innovative and creative solutions.
CO 3	Plan and execute tasks utilizing available resources within timelines, following ethical professional and financial norms.
CO 4	Organize and communicate technical and scientific findings effectively in written reports, oral presentation, and visual aids.

Mapping of course outcomes with program outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 1	3		3	2	2	3	2
CO 2	3		3	3	3	2	
CO 3	3		2		3	3	2
CO 4		3	3	2			2

Assessment Pattern

Mark distribution				Continuous Internal Assessment (CIA) Total Marks: 100	
Total Marks	**CIA**	**ESE**	**ESE Duration**		
100	**100**	--	--	Zeroth evaluation by the Evaluation Committee	--
				Interim evaluation by the Evaluation Committee	**20%**
				Final evaluation by the Evaluation Committee	**40%**
				Project Phase - I Report (By Evaluation Committee)	**20%**
				Project progress evaluation by supervisor	**20%**

The evaluation committee comprises
1-Project Coordinator(s) |2-A Senior faculty member |3-Supervisor of the student

The **Plagiarism level** in the project report shall be less than **25%**.

Interim Review: 20 marks

Literature Survey	CO1	5 marks
Comprehension and Problem Identification.	CO2	5 marks

Objective Identification.	CO2	5 marks
Document Preparation and Presentation.	CO4	5 marks
Final Review: 40 marks		
Literature Survey	CO1	10 marks
Project Design	CO2	10 marks
Execution of tasks by utilizing available resources within timelines	CO3	10 marks
Presentation and document preparation	CO4	10 marks
Evaluation by the supervisor: 20 marks		
The guide/supervisor shall monitor the progress being carried out by the student on a regular basis. In case it is found that progress is unsatisfactory it shall be reported to the Department Evaluation Committee for necessary action.		
Student's Diary/ Log book:		
The main purpose of writing diary/log book is to cultivate the habit of documenting and to encourage the students to search for details. The activity diary shall be signed after every week by the supervisor.		
The minimum attendance for completing the course is **75%**.		
The pass minimum for the course is **50%** for CIA**.**		

SYLLABUS	
DETAILS	**HOURS**
1. Literature study/survey of published literature on the assigned topic 2. Formulation of objectives 3. Formulation of hypothesis/ design/ methodology 4. Formulation of work plan and task allocation. 5. Design documentation 6. Preliminary analysis/ Modelling/ Simulation/ Experiment/ Design/ Feasibility study 7. Preparation of Phase 1 report	**150**

Dissertation outside the Institute: For doing dissertation outside the Institution, the following conditions are to be met:

i. They have completed successfully the course work prescribed in the approved curriculum up to the second semester.
ii. The student has to get prior approval from the DLAC and CLAC.
iii. Facilities required for doing the dissertation shall be available in the Organization/Industry (A certificate stating the facilities available in the proposed organization and the time period for which the facilities shall be made available to the student, issued by a competent authority from the Organization/Industry shall be submitted by the student along with the application).
iv. They should have an external as well as an internal supervisor. The internal supervisor should belong to the parent institution and the external supervisor should be Scientists or Engineers from the Institution/Industry/ R&D organization with which the student is associated for doing the dissertation work. The external supervisor shall be with a minimum post graduate degree in the related area.
v. The student has to furnish his /her monthly progress as well as attendance report signed by the external supervisor and submit the same to the concerned Internal supervisor.
vi. The external supervisor is to be preferably present during all the stages of evaluation of the dissertation.

Internship leading to Dissertation: The M. Tech students who after completion of 6 to 8 weeks internship at some reputed organizations are allowed to continue their work as dissertation for the third and fourth semester after getting approval from the CLAC. Such students shall make a brief presentation regarding the work they propose to carry out before the DLAC for a detailed scrutiny and to resolve its suitability for accepting it as an

M.Tech dissertation. These students will be continuing as regular students of the Institute in third semester for carrying out all academic requirements as per the curriculum/regulation. However, they will be permitted to complete their dissertation in the Industry/Organization (where they have successfully completed their internship) during fourth semester. They should have an external as well as an internal supervisor. The internal supervisor should belong to the parent institution and the external supervisor should be Scientists or Engineers from the external organization with which the student is associated for doing the dissertation work. The external supervisor shall be with a minimum post graduate degree in the related area. The student has to furnish his /her monthly progress as well as attendance report signed by the external guide and submit the same to the concerned internal guide. The external guide is to be preferably present during all the stages of evaluation of the dissertation.

Dissertation as part of Employment: Students may be permitted to discontinue the programme and take up a job provided they have completed all the courses till second semester (FE status students are not permitted) prescribed in the approved curriculum. The dissertation work can be done during a later period either in the organization where they work if it has R&D facility, or in the Institute. Such students should submit application with details (copy of employment offer, plan of completion of their project etc.) to the Dean (PG) through HoD. The application shall be vetted by CLAC before granting the approval. When the students are planning to do the dissertation work in the organization with R&D facility where they are employed, they shall submit a separate application having following details:

i. Name of R&D Organization/Industry
ii. Name and designation of an external supervisor from the proposed Organization/Industry (Scientists or Engineers with a minimum post graduate degree in the related area) and his/her profile with consent
iii. Name and designation of a faculty member of the Institute as internal supervisor with his/her consent
iv. Letter from the competent authority from the Organization/Industry granting permission to do the dissertation
v. Details of the proposed work
vi. Work plan of completion of project

DLAC will scrutinize the proposal and forward to CLAC for approval. When students are doing dissertation work along with the job in the organization (with R & D facility) where they are employed, the dissertation work shall be completed in four semesters normally (two semesters of dissertation work along with the job may be considered as equivalent to one semester of dissertation work at the Institute). Extensions may be granted based on requests from the student and recommendation of the supervisors such that he/she will complete the M. Tech programme within four years from the date of admission as per the regulation. Method of assessment and grading of the dissertation will be the same as in the case of regular students. The course work in the 3rd semester for such students are to be completed as per the curriculum requirements (i) MOOC can be completed as per the norms mentioned earlier (ii) Audit course are to be carried out either in their parent Institution or by self-learning. However, for self- learning students, all assessments shall be carried out in their parent institution as in the case of regular students.

SEMESTER IV

SLOT	COURSE CODE	COURSE NAME	MARKS		L-T-P	Hrs.	CREDIT
			CIA	ESE			
TRACK 1							
A	224PEE100	DISSERTATION PHASE II	100	100	0-0-24	24	16
TRACK 2							
A	224PEE001	RESEARCH PROJECT PHASE II	100	100	0-0-24	24	16
		Total	**100**	**100**		**24**	**16**

224PEE100	DISSERTATION PHASE II	Category	L-T-P-C	YOI
		Project Work	0-0-24-16	2024

All categories of students in track 1 are to carry out the DISSERTATION PHASE II in the institute they are studying or in any Industrial/ R&D organization/any other reputed institute which have facilities for dissertation work in the area proposed. DISSERTATION PHASE II shall not compulsorily continuation of DISSERTATION PHASE I. The student has to publish a research article in a conference or a reputed journal before appearing for the end-semester examination. The eligibility criteria for registering to the end semester examination are attendance in the course and no pending disciplinary action. The minimum attendance for appearing for the end semester examination is 75%. Students who do not meet these eligibility criteria are ineligible (identified by FE grade) to appear for the ESE. Students, who have completed a course but could not appear for the end semester examination, shall be awarded 'AB' Grade, provided they meet other eligibility criteria. The pass minimum for the course is 45% for ESE and 50% for (CIA and ESE) put together.

Assessment Pattern			
Mark distribution			
Total Marks	**CIA**	**ESE**	**ESE Duration**
200	**100**	**100**	--

Continuous Internal Assessment (CIA) Total Marks: 100

Zeroth evaluation by the Evaluation Committee	--
Interim evaluation by the Evaluation Committee	**30%**
Final evaluation by the Evaluation Committee	**50%**
Project progress evaluation by supervisor	**20%**

The evaluation committee comprises

1-Project Coordinator(s)
2-A Senior faculty member
3-Supervisor of the student

Evaluation by the supervisor: 20 marks

The guide/supervisor shall monitor the progress being carried out by the student on a regular basis. In case it is found that progress is unsatisfactory it shall be reported to the Department Evaluation Committee for necessary action.

Student's Diary/ Log book:

The main purpose of writing diary/log book is to cultivate the habit of documenting and to encourage the students to search for details. The activity diary shall be signed after every week by the supervisor.

End Semester Evaluation (ESE) Total Marks: 100

1. Innovation and Originality: Assessment of the uniqueness and innovation demonstrated in the project work. Original contributions, if any, to the field or problem area.	**10%**
2. Implementation and Execution: Evaluation of the actual implementation or execution of the project, including: ✓ Quality of work done ✓ Demonstrated skills and techniques applied ✓ Adherence to project timelines and milestones	**20%**
3. Project Documentation: Comprehensive project report evaluation including: ✓ Introduction and problem statement ✓ Literature review ✓ Methodology and approach ✓ Results and analysis ✓ Conclusion and recommendations ✓ References and citations ✓ Details of the publications ✓ Plagiarism certificate The **Plagiarism level** in the project report shall be less than **25%.**	**25%**
4. Presentation and Defence: Oral presentation of the project to a panel of examiners, including: ✓ Clarity and effectiveness of the presentation ✓ Ability to explain the project objectives, methodologies, and findings ✓ Handling questions and providing satisfactory answers during the defence.	**40%**
5. Publication of the work either in a conference or in a journal:	**05%**
The evaluation committee comprises 1-Project Coordinator(s) 2-An external expert (from Industry or research/academic institute) 3-Supervisor of the student	

SYLLABUS	
DETAILS	**HOURS**
1. Literature study/survey of published literature on the assigned topic 2. Topic Selection and Proposal 3. Formulation of objectives 4. Research and Planning 5. Formulation of work plan and task allocation. 6. Execution 7. Documentation and Reporting 8. Project Showcase reflecting on the project experience and lessons learned	**200**

Dissertation outside the Institute: For doing dissertation outside the Institution, the following conditions are to be met:

vii. They have completed successfully the course work prescribed in the approved curriculum up to the second semester.
viii. The student has to get prior approval from the DLAC and CLAC.
ix. Facilities required for doing the dissertation shall be available in the Organization/Industry (A certificate stating the facilities available in the proposed organization and the time period for which the facilities shall be made available to the student, issued by a competent authority from the Organization/Industry shall be submitted by the student along with the application).
x. They should have an external as well as an internal supervisor. The internal supervisor should belong to the parent institution and the external supervisor should be Scientists or Engineers from the Institution/Industry/ R&D organization with which the student is associated for doing the dissertation work. The external supervisor shall be with a minimum post graduate degree in the related area.
xi. The student has to furnish his /her monthly progress as well as attendance report signed by the external supervisor and submit the same to the concerned internal supervisor.
xii. The external supervisor is to be preferably present during all the stages of evaluation of the dissertation.