INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad -500 043

ELECTRICAL AND ELECTRONICS ENGINEERING

COURSE DESCRIPTOR

Course Title	**HYBRID ELECTRIC VEHICLES**				
Course Code	AEE019				
Programme	B. Tech				
Semester	VIII	EEE			
Course Type	Core				
Regulation	IARE - R16				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	1	4	-	-
Chief Coordinator	P. Sindhu, Assistant Professor				
Course Faculty	P. Sindhu, Assistant Professor				

I. COURSE OVERVIEW:

This course introduces the fundamental concepts, principles and analysis of hybrid and electric vehicles and goes deeper into the various aspects of hybrid and electric drive train such as their configuration, types of electric machines that can be used, and energy storage devices.

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites	Credits
UG	AEE013	VI	Solid State Electric Motor Drives	4

III. MARKS DISTRIBUTION:

Subject	SEE Examination	CIA Examination	Total Marks
Hybrid Electric Vehicles	70 Marks	30 Marks	100

IV. DELIVERY / INSTRUCTIONAL ETHODOLOGIES:

✗	Chalk & Talk	✔	Quiz	✔	Assignments	✗	MOOCs
✔	LCD / PPT	✔	Seminars	✗	Mini Project	✔	Videos
✔	Open Ended Experiments						

V. EVALUATION METHODOLOGY:

The course will be evaluated for a total of 100 marks, with 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). Out of 30 marks allotted for CIA during the semester, marks are awarded by taking average of two CIA examinations or the marks scored in the make-up examination.

Semester End Examination (SEE): The SEE is conducted for 70 marks of 3 hours duration. The syllabus for the theory courses is divided into five units and each unit carries equal weightage in terms of marks distribution. The question paper pattern is as follows. Two full questions with "either" or "choice" will be drawn from each unit. Each question carries 14 marks. There could be a maximum of two sub divisions in a question.

The emphasis on the questions is broadly based on the following criteria:

50 %	To test the objectiveness of the concept.
50 %	To test the analytical skill of the concept OR to test the application skill of the concept.

Continuous Internal Assessment (CIA):
CIA is conducted for a total of 30 marks (Table 1), with 25 marks for Continuous Internal Examination (CIE), 05 marks for Quiz/ Alternative Assessment Tool (AAT).

Table 1: Assessment pattern for CIA

Component	**Theory**		**Total Marks**
Type of Assessment	CIE Exam	Quiz / AAT	
CIA Marks	25	05	30

Continuous Internal Examination (CIE):
Two CIE exams shall be conducted at the end of the 8th and 16th week of the semester respectively. The CIE exam is conducted for 25 marks of 2 hours duration consisting of two parts. Part–A shall have five compulsory questions of one mark each. In part–B, four out of five questions have to be answered where, each question carries 5 marks. Marks are awarded by taking average of marks scored in two CIE exams.

Quiz / Alternative Assessment Tool (AAT):
Two Quiz exams shall be online examination consisting of 25 multiple choice questions and are be answered by choosing the correct answer from a given set of choices (commonly four). Marks shall be awarded considering the average of two quizzes for every course. The AAT may include seminars, assignments, term paper, open ended experiments, five minutes video and MOOCs.

VI. HOW PROGRAM OUTCOMES ARE ASSESSED:

Program Outcomes (POs)		Strength	Proficiency assessed by
PO1	**Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	3	Assignments and seminar
PO2	**Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences	2	Assignments and seminar
PO4	**Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.	2	Assignments and seminar
PO7	**Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.	3	Assignments and seminar

3 = High; 2 = Medium; 1 = Low

VII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Specific Outcomes (PSOs)		Strength	Proficiency assessed by
PSO 1	**Problem Solving**: Exploit the knowledge of high voltage engineering in collaboration with power systems in innovative, dynamic and challenging environment, for the research based team work.	--	--
PSO 2	**Professional Skills**: Identify the scientific theories, ideas, methodologies and the new cutting edge technologies in renewable energy engineering, and use this erudition in their professional development and gain sufficient competence to solve the current and future energy problems universally	3	seminar
PSO 2	**Modern Tools in Electrical Engineering:** Comprehend the technologies like PLC, PMC, process controllers, transducers and HMI and design, install, test, maintain power systems and industrial applications.	--	--

3 = High; 2 = Medium; 1 = Low

VIII. COURSE OBJECTIVES (COs):

The course should enable the students to:	
I	Interpret the social and environmental importance of hybrid and electrical vehicles
II	Discuss the concept of hybrid traction and electric traction with the help of hybrid drive train and electric drive train topologies.
III	Explain the electric propulsion unit of hybrid electric vehicles.
IV	Understand the configuration and control of different types of electric drives.
V	Demonstrate the concepts of energy storage and energy management in hybrid electric vehicles.

IX.COURSE OUTCOMES (COs):

COs	Course Outcome	CLOs	Course Learning Outcome
CO1	Impact of Conventional Vehicles on The Society and Different Types of Drive Train Topologies.	CLO 1	Explain the social and environmental importance of hybrid and electric vehicles.
		CLO 2	Describe the performance of hybrid and Electric vehicles.
		CLO 3	Discuss the basic concepts of hybrid traction, introduction to various hybrid drive-train topologies.
CO2	Load Modelling Based on The Road Profile and Braking concepts.	CLO 4	Discuss the basic concepts of electric traction.
		CLO 5	Explain power flow control in hybrid and electric drive train topologies
		CLO 6	Analyze the fuel efficiency of hybrid and electric drives.
CO3	Different types of Motors used in Hybrid Electric Vehicles Concept.	CLO 7	Examine the configuration and control of DC motor drives.
		CLO8	Illustrate the configuration and control of induction motor drives
		CLO9	Classify the configuration and control of permanent magnet motor drives.
		CLO 10	Explain the configuration and control of switched reluctance motor drives.
CO4	Different types of Energy Storage Systems used in Hybrid Electric Vehicles.	CLO11	Discuss the energy storage requirements in hybrid and electric vehicles.
		CLO12	Analyze the various energy storage systems based on battery and fuel cell.
		CLO13	Analyze the various energy storage systems based on super capacitor and flywheel.
		CLO14	Explain the hybridization of various energy storage devices, its advantages and challenges.
CO5	The Concept of Energy Management Strategies Used in Hybrid Electric Vehicles.	CLO15	Classify different energy management strategies used in hybrid and electric vehicles.
		CLO16	Discuss the implementation issues of energy management strategies
		CLO17	Understand the impact of the professional engineering solutions in societal and environmental contexts.
		CLO18	Explore the knowledge and skills of employability to succeed in national and international level competitive examinations

X.COURSE LEARNING OUTCOMES (CLOs):

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's Mapped	Strength of Mapping
AEE019.01	CLO 1	Explain the social and environmental importance of hybrid and electric vehicles.	PO 7	3
AEE019.02	CLO 2	Describe the performance of hybrid and electric vehicles.	PO 1	3
AEE019.03	CLO 3	Discuss the basic concepts of hybrid traction, introduction to various hybrid drive-train topologies	PO 1	3
AEE019.04	CLO 4	Discuss the basic concepts of electric traction	PO 1	3

AEE019.05	CLO 5	Explain power flow control in hybrid and electric drive train topologies	PO 1	3
AEE019.06	CLO 6	Analyze the fuel efficiency of hybrid and electric drives	PO 2	2
AEE019.07	CLO 7	Examine the configuration and control of DC motor drives.	PO 2	2
AEE019.08	CLO 8	Illustrate the configuration and control of induction motor drives.	PO 4	2
AEE019.09	CLO 9	Classify the configuration and control of permanent magnet motor drives.	PO 2	2
AEE019.10	CLO 10	Explain the configuration and control of switched reluctance motor drives.	PO 2	2
AEE019.11	CLO 11	Discuss the energy storage requirements in hybrid and electric vehicles.	PO 1	3
AEE019.12	CLO 12	Analyze the various energy storage systems based on battery and fuel cell.	PO 2	2
AEE019.13	CLO 13	Analyze the various energy storage systems based on super capacitor and flywheel.	PO 2	3
AEE019.14	CLO 14	Explain the hybridization of various energy storage devices, its advantages and challenges.	PO 1, PO 2	3
AEE019.15	CLO 15	Classify different energy management strategies used in hybrid and electric vehicles.	PO 2	2
AEE019.16	CLO 16	Discuss the implementation issues of energy management strategies	PO 2	2
AEE019.17	CLO 17	Understand the impact of the professional engineering solutions in societal and environmental contexts.	PO 4, PO 7	3
AEE019.18	CLO 18	Explore the knowledge and skills of employability to succeed in national and international level competitive examinations	PO 1, PO 2	3

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XI.MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES

Course Outcomes (COs)	Program Outcomes (POs)			
	PO 1	PO 2	PO 4	PO7
CO 1	3	2	**1**	3
CO 2	2	3	3	1
CO 3	2	3	3	1
CO 4	3	3	3	2
CO 5	3	2	1	3

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XII. MAPPING COURSE LEARNING OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

(CLOs)	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CLO 1							3							3	
CLO 2	3														
CLO 3	3														
CLO 4	3														
CLO 5	3														
CLO 6		2												3	
CLO 7		2													
CLO 8				2											
CLO 9		2													
CLO 10		2													
CLO 11	3														
CLO 12		2													
CLO 13		2												3	
CLO 14	3	2													
CLO 15		2													
CLO 16		2													
CLO 17				2			3							3	
CLO 18	3	2												3	

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XIII.ASSESSMENT METHODOLOGIES – DIRECT

CIE Exams	PO1, PO2, PSO1	SEE Exams	PO1,PO2, PSO2,	Assignments	PO1, PO2	Seminars	PO4, PO7
Laboratory Practices	-	Student Viva	-	Mini Project	-	Certification	-
Term Paper	-						

XIV.ASSESSMENT METHODOLOGIES – INDIRECT

✔	Early Semester Feedback	✔	End Semester OBE Feedback
✗	Assessment of Mini Projects by Experts		

XV.SYLLABUS

UNIT-I	INTRODUCTION
Introduction to Hybrid Electric Vehicles: History of hybrid and electric vehicles, social and environmental importance of hybrid and electric vehicles, impact of modern drive-trains on energy supplies; Conventional Vehicles: Basics of vehicle performance, vehicle power source Characterization, transmission characteristics, and mathematical models to describe vehicle performance.	
UNIT-II	**HYBRID ELECTRIC DRIVE TRAINS**
Hybrid Electric Drive trains: Basic concept of hybrid traction, introduction to various hybrid drive-train topologies, power flow control in hybrid drive train topologies, fuel efficiency analysis; Electric Drive trains: Basic concept of electric traction, introduction to various electric drive train topologies, power flow control in electric drive train topologies, fuel efficiency analysis.	
UNIT-III	**ELECTRIC MOTORS FOR HYBRID ELECTRIC VEHICLES**
Electric Propulsion unit: Introduction to electric components used in hybrid and electric vehicles, configuration and control of DC motor drives, configuration and control of Induction Motor drives. Configuration and control of permanent magnet motor drives, configuration and control of switch reluctance motor drives, drive system efficiency.	
UNIT-IV	**ENERGY STORAGE**
Energy Storage: 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, super capacitor based energy storage and its analysis, flywheel based energy storage and its analysis, 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, selecting the energy storage technology, communications, supporting subsystems.	
UNIT-V	**ENERGY MANAGEMENT STRATEGIES**
Energy Management Strategies: Introduction to energy management strategies used in hybrid and electric vehicles, classification of different energy management strategies, comparison of different energy management strategies, implementation issues of energy management strategies.	
Text Books:	
1. Iqbal Hussein, "Electric and Hybrid Vehicles: Design Fundamentals", CRC Press, 2nd Edition, 2003. 2. James Larminie, John Lowry, "Electric Vehicle Technology", Wiley publications, 1st Edition, 2003. 3. Mehrdad Ehsani, Yimi Gao, Sebastian E Gay, Ali Emadi, "Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals Theory and Design", CRC Press, 2nd Edition,2004.	
Reference Books:	
1. B D Mc Nicol, D A J Rand, "Power Sources for Electric Vehicles", Elsevier publications, 1st Edition, 1998. 2. Seth Leitman, "Build Your Own Electric Vehicle" McGraw Hill, 1st Edition, 2013. 3. Jeffrey Gonder, Tony Markel, "Energy Management Strategies for Plug-In Hybrid Electric Vehicles", 2007-01-0290, National Renewable Energy Laboratory.	

XVI.COURSE PLAN:

The course plan is meant as a guideline. Probably there may be changes.

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
1	Explain air pollution and global warming.	CLO 1	T3:1.1 R2:2.1
2	Describe the impact of different transportation technologies on environment	CLO 1	T1:1.5 R2:2.4
3	Summarize the history of hybrid electric, electric and fuel cell vehicles.	CLO 2	T1:1.6 R2:2.6
4	Explain the impact of modern drive-trains on energy supplies	CLO 4	T1:1.6 R2:4.10
5	Illustrate the impact of modern drive-trains on energy supplies	CLO 4	T1:1.6 R2:2.4
6	Explain the transmission characteristics of conventional vehicles	CLO 5	T1:1.6 R2:2.4
7	Discuss vehicle power source characterization	CLO 6	T1:1.6 R2:2.4
8	Explain the mathematical models to describe vehicle performance	CLO 6	T1:2.6 R2:5.1
9	Discuss the basic concepts of hybrid traction	CLO 4	T3:2.6 R2:7.5
10	Classify the various hybrid drive-train topologies	CLO 3	T3:2.7 R2:8.1
11	Outline power flow control in hybrid drive train topologies	CLO 5	T3:2.7 R2:9.2
12	Classify electric drive train topologies	CLO 4	T3:2.8 R2:9.4
13	Analyze the fuel efficiency of hybrid and electric drives	CLO 6	T3:2.8 R2:9.10
14	Explain the concept of electric traction	CLO 4	T3:5.1 R2:10.2
15	Illustrate electric drive train topologies	CLO 4	T3:5.1 R2:11.3
16	Understand power flow control in electric drive train topologies	CLO 5	T3:5.2 R2:11.7
17	Understand power flow control in electric drive train topologies	CLO 5	T3:5.2 R2:11.8
18	Analyze the fuel efficiency of electric drive trains	CLO 6	T3:4.2 R2:11.9
19	Summarize the electric components used in hybrid and electric vehicles	CLO 5	T3:5.1 R2:12.3
20	Explain the electric components used in hybrid and electric vehicles in detail.	CLO 5	T3:6.1 R2:12.7
21	Explain the electric drives used in HEV/EVs, their classifications and general characteristics	CLO 5	T3:6.1 R2:12.15
22	Describe DC Motor drives, their configuration and principle of operation	CLO 7	T3:6.1 R2:6.1
23	Explain the performance and control of DC motor drives	CLO 7	T3:6.1 R2:6.1
24	Discuss the configurations of induction motor drives for HEV	CLO 8	T3:6.3 R2:6.1
25	Explain the control of induction motor drives	CLO 8	T3:6.3 R2:6.1
26	Discuss the configuration and control of permanent magnet motor	CLO 9	T3:6.3
	drives		R2:6.1

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
27	Illustrate the configuration and control of switch reluctance motor drives	CLO 10	T3:6.4 R2:6.1
28	Explain drive system efficiency	CLO 10	T3:6.5 R2:6.1
29	Outline the energy storage requirements in hybrid and electric vehicles	CLO 11	T3:10.1 R2:8.1
30	Analyze battery based energy storage systems	CLO 12	T3:10.1 R2:8.1
31	Analyze fuel cell based energy storage systems	CLO 12	T3:10.1 R2:8.1
32	Outline the different energy management strategies used in hybrid and electric vehicles	CLO 12	T3:12.1 R2:8.1
33	Explain super capacitor based energy storage and its analysis	CLO 13	T3:12.1 R2:8.1
34	Discuss flywheel based energy storage and its analysis	CLO 13	T3:12.1 R2:8.1
35	Explain hybridization of different energy storage devices	CLO 14	T3:12.1 R2:8.1
36	Interpret the matching of electric drives and ICE	CLO 14	T3:10.1 R2:8.1
37	Explain the sizing of propulsion motor	CLO 14	R2:8.1
38	Discuss the sizing of power electronics	CLO 14	T3:10.1 R2:8.1
38	Explain the selecting of suitable the energy storage technology	CLO 11	T3:12.1 R2:8.1
39	Describe communications and supporting subsystems	CLO 14	T3:12.1 R2:8.1
39-40	Energy management strategies and its general architecture	CLO 15	T3:10.1 R3:1.1
41-42	Classify energy management strategies used in hybrid and electrical vehicles	CLO 16	T3:10.2 R3:1.1
42-43	Compare different energy management strategies	CLO 16	T3:10.1 R3:1.1
44-45	Discuss the implementation issues of energy management strategies	CLO 15	T3:10.1 R3:1.1

XVII.GAPS IN THE SYLLABUS - TO MEET INDUSTRY / PROFESSION REQUIREMENTS:

S No	Description	Proposed actions	Relevance with POs	Relevance with PSOs
1	Systems of electric traction	Seminars	PO 1	PSO 2

Prepared By:
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HOD, EEE