UNIVERSITY OF MUMBAI

Syllabus

Honours/Minor Degree Program

In

Electric Vehicles

FACULTY OF SCIENCE & TECHNOLOGY

(As per AICTE guidelines with effect from the academic year 2022-2023)

University of Mumbai Electric Vehicles (With effect from 2022-23)										
Year & Sem	**Course Code and Course Title**	**Teaching Scheme Hours / Week**			**Examination Scheme and Marks**					**Credit Scheme**
		Theory	Seminar/ Tutorial	Pract	Internal Assessment	End Sem Exam	Term Work	Oral/ Pract	Total	Credits
TE Sem V	**HCEV501: Vehicular Systems and Dynamics**	04	--	--	20	80	--	--	100	04
	Total	**04**	**-**	**--**	**100**		**-**	**-**	**100**	**04**
									Total Credits =	**04**
TE Sem. VI	**HCEV601: EV Drive and Energy Sources**	04	--	--	20	80	--	--	100	04
	Total	**04**	**-**	**-**	**100**		**-**	**-**	**100**	**04**
									Total Credits =	**04**
BE Sem. VII	**HCEV701: Automotive Controllers and Auxiliary Systems**	04	--	--	20	80	--	--	100	04
	HSEVBL701: Electric Vehicles Lab	--	--	04	--	--	50	50	100	02
	Total	**04**	**-**	**04**	**100**		**50**	**50**	**200**	**06**
									Total Credits =	**06**
BE Sem. VIII	**HCEV801: Electric Vehicle System Design**	04	-	--	20	80	--	--	100	04
	Total	**04**	**-**	**-**	**100**		**-**	**-**	**100**	**04**
									Total Credits =	**04**
Total Credits for Semesters V,VI, VII &VIII = 04+04+06+04 = 18										

'Electric Vehicle' - SEM-V						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Tutorial	Theory	Tutorial	Total
HCEV501	**Vehicular Systems and Dynamics**	04	-	04	-	04

Course code	Course Name	Examination Scheme						
		Theory					Term Work	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)		
		Test 1	Test 2	Avg.				
HCEV501	**Vehicular Systems and Dynamics**	20	20	20	80	03	-	100

Course Objectives	1. To study different automotive components and subsystems 2. To explore and compare the transition of automotive domain from ICE to electric vehicles
Course Outcomes	**Upon successful completion of this course, the learner will be able:** 1. To Illustrate the general configuration and identify various components of automobile. 2. To define the functionality and working principles of different types of Automotive Powertrains 3. To illustrate the working of various automotive transmission systems 4. To identify and illustrate the various hybrid electric powertrains and their different modes of operations 5. To explain the basic and state of the art of Electric vehicles and its major parts. 6. To compare and contrast the performance of ICE vehicles, HEVs and EVs.

Module	Contents	Hours
1.	**Vehicle Mechanics:** History of Vehicle Development, General Configuration of Automobile, Body and Chassis Fundamentals: General Packaging, Types of Structural System, Backbone Construction; Body and Chassis Materials. Automotive Powertrain Mechanical, Suspensions system, Steering System, NVH, Control System Integration and Implementation. Front-Wheel Drive (FWD) Powertrains, Rear-Wheel Drive Powertrains (RWD), Multi-Wheel Drive Powertrains (AWD and 4WD)	10
2.	**Transmission Systems:** Transmission gears, Manual Transmission (MT), Automatic Transmission (AT), Automated Manual Transmissions (AMT) and Continuously Variable Transmissions (CVT); Manual Transmissions Powertrain Layout and Manual Transmission Structure, Power Flows and Gear Ratios, Manual Transmission Clutch and its structure. Drivetrain and Differential	10
3.	**Automotive Subsystems:** Automotive Aero-dynamics, Vehicle Power Demand Analysis; Types of suspension and drive, Braking systems; Tyre Mechanics: Tyres and wheels, Tyre characteristics; Vehicle handling & stability; Automotive instrumentation	06
4.	**ICE Performance Characteristics:** Power and torque generation, specific fuel consumption, specific emissions, Efficiencies- fuel conversion efficiency, mechanical efficiency, volumetric efficiency	06

5.	**Hybrid Powertrain:** Series HEVs, Parallel HEVs, Series–Parallel HEVs, Complex HEVs, Operating Modes, Degree of Hybridization, Comparison of HEVs, Plug-in Hybrid Electric Vehicles (PHEVs) Real Life examples of HEVs	10
6.	**Electric Vehicles:** Basics of Electric Vehicles, Current Status and Trends for EVs, Battery Electric Vehicles (BEVs), Fuel-Cell Electric Vehicles (FCEVs), Electric Machines for EV applications, EV Transmission: Single-Speed EV Transmission, Multiple Ratio EV Transmissions. Comparison of ICE vehicle with HEVs and EVs. National Policy for adoption of EVs	10

Text Books:-

1. Vehicle Powertrain Systems by Behrooz Mashadi and David Crolla, Wiley, 2012
2. Automotive Aerodynamics by Joseph Katz, Wiley, 2016
3. Automotive Chassis Engineering, by David C. Barton and John D. Fieldhouse, Springer, 2018
4. Automotive Engineering Powertrain, Chassis System and Vehicle Body Edited by David A. Crolla, Elsevier, 2009
5. Automotive Power Transmission Systems by Yi Zhang and Chris Mi, Wiley, 2018
6. Linear Electric Machines, Drives, and MAGLEVs Handbook, by Ion Boldea, CRC Press. 2013
7. Modern Electric, Hybrid Electric, and Fuel Cell Vehicles by Mehrdad Ehsani, Yimin Gao, Sebastien E. Gay, and Ali Emadi, CRC Press 2005
8. Electric Vehicle Technology Explained by James Larminie and John Lowry, John Wiley, 2003
9. Electric And Hybrid Vehicles- Design Fundamentals by Iqbal Husain, CRC Press, 2005

Reference Books:-

1. Encyclopaedia of Automotive Engineering edited by David Crolla et al, Wiley, 2014
2. Design and Control of Automotive Propulsion Systems by Zongxuan Sun and Guoming Zhu, CRC Press, 2015
3. The Automotive Transmission Book by Robert Fischer, Ferit Küçükay, Gunter Jürgens , Rolf Najork, and Burkhard Pollak, Springer, 2015
4. Noise and Vibration Control in Automotive Bodies by Jian Pang, Wiley, 2019

Website Reference / Video Courses:

1. NPTEL Web course: Fundamentals of Automotive Systems, by Prof. C.S. Shankar Ram, IIT Madras, https://nptel.ac.in/courses/107/106/107106088/

Assessment:

Internal Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project

Theory Examination:

1. Question paper will comprise of 6 questions, each carrying 20 marks.
2. Total four questions need to be solved.
3. Q.1 will be compulsory, based on entire syllabus wherein sub questions of 2 to 5 marks will be asked.

4. Remaining question will be randomly selected from all the modules.

'Electric Vehicle' - SEM-VI						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Tutorial	Theory	Tutorial	Total
HCEV601	**EV Drive and Energy Sources**	04	-	04	-	04

Course code	Course Name	Examination Scheme						
		Theory					Term Work	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)		
		Test 1	Test 2	Avg.				
HCEV601	**EV Drive and Energy Sources**	20	20	20	80	03	-	100

Course Objectives	1. To explore and understand various traction motors, power drives and control strategies used in EVs. 2. To get conversant with the energy sources used in EVs and their state of the art. 3. To understand the various battery charging and management systems
Course Outcomes	Upon successful completion of this course, the learner will be able to: 1. To identify and assess various traction motors along with their suitability in various EV segments 2. To describe and differentiate various power converters and their control used in EV drives 3. To evaluate the battery specifications using various design considerations for EVs 4. To illustrate different battery charging methods and protocols 5. To explain the impact of large scale integration of EV charging infra in existing grid and its mitigation techniques. 6. To illustrate the need and importance of drive cycles used in testing of automobiles.

Module	Contents	Hours
1.	**Introduction to Traction Motors:** DC Machines- Brushed and Brushless DC motors (BLDC); AC Motors: Induction motors (IM), permanent-magnet ac synchronous motor-surface-permanent-magnet (SPM) motors and interior-permanent-magnet (IPM) motors; PM Materials; Switched Reluctance Motor (SRM); Basic construction details and working principles of each of the machine. In-Wheel Motors Comparison of Traction Machines; Specifications of the motors, Characteristic Curves of a Machines: Constant-Torque Mode, Constant-Power Mode; Efficiency Map; Suitability of each machine in Electric vehicle domain for 2W, 3W, 4 wheeler and large size vehicles. Real life examples; Review of advancement in EV Motors and Drives.	10
2.	**Power Converters for EV drive:** Power Conversion –Basic Principle, review of DC-DC converters, DC-AC Converters used in EV applications; Power topologies for IM, BLDC, PMSM and SRM motors. Traction Drives, Modulation schemes: Sinusoidal Pulse Width Modulation, SPWM with third harmonic injection, Space vector modulation, comparison of modulation techniques. Converter / Inverter Loss calculation, Heat-sinking: passive and active cooling.	08

3.	**Control of Power converters and Motors:** Induction Motor Control: Variable-Voltage Variable-Frequency Control (VVVF), Field-Oriented Control (FOC), Direct Torque Control (DTC); PM Synchronous Motor Control: Field-Oriented Control of PMSM, Flux-Weakening Control of PMSM, Position Sensorless Control of PMSM. SRM motor control: Current chopping control (CCC), Torque-Ripple Minimization Control BLDC Motor Control*:* Trapezoidal back EMF BLDC motor control	10
4.	**Energy Sources for EV:** Overview of energy sources for electric vehicle: Batteries, Fuel Cell, Ultra-capacitor and flywheel energy storage; Hybridization of energy sources for electric and hybrid vehicles; Comparison of sources. Batteries: Lead-acid battery, Nickel-based batteries, Sodium based batteries, lithium batteries Metal/air batteries; Battery parameters, Battery pack formation and testing, SoC & SoH, Estimation of SoC. Battery cell balancing, Battery management System (BMS), Thermal and safety considerations in battery pack design. Voltage and AHr/ kWhr ratings of ES for EV applications: Major design considerations	10
5.	Battery charging Infrastructure: AC and DC charging, CC-CV charging, Pulse charging; On-board and off-board charging; Standards and protocols for charging; Fast DC chargers, Home and Public charging infrastructure; Wireless power transfer (WPT) technologies for EVs, Move-and-charge technology. Charging Infrastructure-standardization and connectivity issues; SAE J1772, CHAdeMo, GB/T, CCS2 battery charging protocols. OCPP protocol Impact on existing power grid, G2V and V2X- Vehicle-to-home (V2H), vehicle-to-vehicle (V2V), and vehicle-to-grid (V2G) energy systems. Renewable Energy Based Charging infra.	10
6.	**EV Drive Cycle Testing:** Need for a driving cycle, different Drive Cycles: NEDC, EUDC, EPA, WLTP, and FTP-75; Testing of EV for range per charge for a given drive cycle	04

Text/Reference Books:-

1. Fundamentals And Applications Of Lithium-Ion Batteries In Electric Drive Vehicles by Jiuchun Jiang and Caiping Zhang, Wiley, 2015
2. Battery Management Systems for Large Lithium-Ion Battery Packs, by Davide Andrea, Artech House Publication, 2010
3. Electric Vehicle Battery Systems by Sandeep Dhameja, Newens, 2002
4. Fundamentals And Applications Of Lithium-Ion Batteries In Electric by Jiuchun Jiang and Caiping Zhang, Wiley, 2015
5. Optimal Charging Control of Electric Vehicles in Smart Grids by Wanrong Tang and Ying Jun Zhang, Springer, 2017
6. Plug In Electric Vehicles in Smart Grids Charging Strategies Edited by Sumedha Rajakaruna, Farhad Shahnia and Arindam Ghosh, Springer 2015
7. Technologies and Applications for Smart Charging of Electric and Plug-in Hybrid Vehicles edited by Ottorino Veneri, Springer, 2017

8. Solar Powered Charging Infrastructure for Electric Vehicles A Sustainable Development Edited by Larry E. Erickson, Jessica Robinson, Gary Brase, and Jackson Cutsor, CRC Press, 2017
9. Energy Systems for Electric and Hybrid Vehicles Edited by K.T. Chau, IET, 2016
10. Handbook of Automotive Power Electronics and Motor Drive Edited by Ali Emadi, CRC Press, 2005
11. Electric And Hybrid Vehicles Power Sources, Models, Sustainability, Infrastructure And The Market by Gianfranco Pistoia, Elsevier, 2013
12. AC Motor Control and Electrical Vehicle Applications, Second Edition by Kwang Hee Nam CRC Press, 2019

Website Reference / Video Courses:

1. NPTEL Web Course: Electric Vehicles - Part 1 by PROF. AMIT KUMAR JAIN Department of Electrical Engineering IIT Delhi; https://nptel.ac.in/courses/108/102/108102121/
2. NPTEL Web Course: Fundamentals of Electric vehicles: Technology & Economics: by Prof. Ashok Jhunjhunwala, Prof. Prabhjot Kaur, Prof. Kaushal Kumar Jha and Prof. L Kannan, IIT Madras, https://nptel.ac.in/courses/108/106/108106170/
3. NPTEL Web Course: Introduction to Hybrid and Electric Vehicles by Dr. Praveen Kumar and Prof. S. Majhi, IIT Guwahati, https://nptel.ac.in/courses/108/103/108103009/

Assessment:

Internal Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project

Theory Examination:

1. Question paper will comprise of 6 questions, each carrying 20 marks.
2. Total four questions need to be solved.
3. Q.1 will be compulsory, based on entire syllabus wherein sub questions of 2 to 5 marks will be asked.
4. Remaining question will be randomly selected from all the modules.

'Electric Vehicle' - SEM-VII						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Tutorial	Theory	Tutorial	Total
HCEV701	**Automotive Controllers and Auxiliary Systems**	04	-	04	-	04

Course code	Course Name	Examination Scheme						
		Theory					Term Work	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)		
		Test 1	Test 2	Avg.				
HCEV701	**Automotive Controllers and Auxiliary Systems**	20	20	20	80	03	-	100

Course Objectives	1. To Identify functionalities of various automotive controllers and auxiliary systems 2. To study various automotive sensors and actuators 3. To explore details of energy sources management system, thermal management system and overall system integration in EVs/ HEVs
Course Outcomes	Upon successful completion of this course, the learner will be able: 1. To illustrate functionality of various auxiliary subsystems used EVs 2. To demonstrate the use of VCUS and ECUS in automobile 3. To describe the need and functionality of automotive sensors / actuators and networking 4. To illustrate the design and management aspects of EV energy sources 5. To describe the various heat losses, and thermal management systems incorporated in EVs 6. To elaborate on System Integration and resource optimization in EVs

Module	Contents	Hours
1.	**Introduction:** Review of Automotive electrical, electronic, communication and thermal subsystems; Review of Energy Storage (Power Plant) system, Main Traction Inverter, On-Board Charger (OBC), LV Auxiliary Power Source, HV Battery Disconnect; Vehicle Control Unit (VCU) and ECUs. Braking Systems: Energy Consumption in Braking, Braking Power and Energy on Front and Rear Wheels, Brake System of EVs and HEVs, Series Brake-Optimal Feel, Series Brake-Optimal Energy Recovery; Parallel Brake; Antilock Brake System (ABS); Fundamentals of Regenerative Braking. Steering System: In-car system networking, Steering ratio characteristic, Steering Stabilization, Over-steer, understeer, Electric-Power-Assisted Steering (EPAS); Autonomous vehicles, Principle of object detection.	12
2.	**Vehicle Control Unit and Electronic Control Unit:** VCU functionality: Inverter control, battery management, charging control, vehicle functions in transmission and engine control; Advanced Driver Assistance System (ADAS); Electronic control units (ECUs): Various Section ECUs and their networking; Body and Lighting ECU (Key-less Entry, Sonar, HID, LED Lamps), Body ECU (Airbag).	08

3.	**Automotive sensors / actuators and networking:** Radar Sensor Detectors for Vehicle Safety Systems; Airborne Ultrasonic Imaging: SONAR Based Image Generation for Autonomous Vehicles, Motor angle sensor, Steering angle sensor, Tyre Pressure Monitoring Systems (TPMS); In Vehicle communication system: CAN, LIN, Ethernet, Flexray	10
4.	**Energy Storage (Power Plant) Management system:** Battery cell packaging, Battery Management System (BMS), Design of battery pack and safety considerations; High voltage cabling and cut-outs; Battery pack installation. Use of Battery-UC Hybrid source; Fuel Cell (FC): FC management and Hydrogen storage in EV.	10
5.	**Thermal Management System:** Heat Calculation in various subsystems; HVAC system: HVAC compressor drive; Liquid cooling system for Battery, Electric drive and On board charger. Design considerations for thermal management system	06
6.	**System Integration and Implementation:** Vehicular Power Control Strategy and Energy Management: A Generic Framework, Definition, and Needs, Methodologies for Optimization, Cost Function Optimization, Benefits of Energy Management.	06

Text/Reference Books:-

1. Electric Powertrain Energy Systems, Power Electronics and Drives for Hybrid, Electric and Fuel Cell Vehicles by John G. Hayes and G. Abas Goodarzi, Wiley, 2018.
2. Handbook of Automotive Power Electronics and Motor Drive Edited by Ali Emadi, CRC Press, 2005
3. Encyclopaedia of Automotive Engineering edited by David Crolla *et al.*, Wiley, 2014
4. Electric and Hybrid Vehicles Technologies, Modeling and Control: A Mechatronic Approach by Amir Khajepour, Saber Fallah and Avesta Goodarzi, Wiley, 2014.
5. Hybrid Electric Vehicles Principles and Applications with Practical Perspectives, Second Edition Chris Mi and M. Abul Masrur, Wiley 2018.
6. Autonomous Vehicles Intelligent Transport Systems And Smart Technologies edited by Nicu Bizon, Lucian Dascalescu and Naser Mahdavi Tabatabaei, Nova Publishers, 2014
7. Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles by Sheldon S. Williamson, Springer, 2013
8. Electric and Hybrid Buses for Urban Transport Energy Efficiency Strategies, by Bogdan Ovidiu Varga, Calin Iclodean and Florin Mariasiu, Springer, 2016

Website Reference / Video Courses:

1. NPTEL Web Course: Electric Vehicles - Part 1 by PROF. AMIT KUMAR JAIN Department of Electrical Engineering IIT Delhi; https://nptel.ac.in/courses/108/102/108102121/
2. NPTEL Web Course: by Fundamentals of Electric vehicles: Technology & Economics: Prof. Ashok Jhunjhunwala, Prof. Prabhjot Kaur,Prof. Kaushal Kumar Jha andProf. L Kannan, IIT Madras, https://nptel.ac.in/courses/108/106/108106170/
3. NPTEL Web Course: Introduction to Hybrid and Electric Vehicles by Dr. Praveen Kumar and Prof. S. Majhi, IIT Guwahati, https://nptel.ac.in/courses/108/103/108103009/

Assessment:

Internal Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project

Theory Examination:

1. Question paper will comprise of 6 questions, each carrying 20 marks.
2. Total four questions need to be solved.
3. Q.1 will be compulsory, based on entire syllabus wherein sub questions of 2 to 5 marks will be asked.
4. Remaining question will be randomly selected from all the modules.

'Electric Vehicle' - SEM-VII						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Practical/ Tutorial	Theory	Practical/ Tutorial	Total
HCEVSBL701	**Electric Vehicles Lab**		04	--	04	04

Course code	Course Name				Examination Scheme				
		Theory					Term Work	Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)			
		Test 1	Test 2	Avg.					
HCEVSBL701	**Electric Vehicles Lab**	-	-	-	-	-	50	50	100

Course Objectives	1. To provide hands-on with various major components used in EV/HEVs 2. To explore EV drives & control implementation along with analysis using simulation tool or with hardware. 3. To study various auxiliary systems commonly used in EV.
Course Outcomes	Upon successful completion of this course, the learner will be able to: 1. Compare and contrast conventional vehicles and EV/HEVs. 2. Illustrate operations and features of Conventional, hybrid electric vehicle and electrical vehicle Powertrains. 3. Describe the working of EV drives used for different kinds of electric motors. 4. Illustrate battery characteristics and working of BMS. 5. Describe the operation of On-board and Off-board EV chargers 6. Demonstrate the use of simulations tools along with hardware implementation for evaluation of EV subsystems.

Contents

Electric Vehicles Lab: Experimental study based on the following topics

1. Conventional and electrical vehicle sub-systems and components
2. Conventional, hybrid electric vehicle and electrical vehicle Powertrains
3. Motor performance test - for BLDC /PMSM/ IM/SRM motors;
4. EV drive for BLDC/PMSM/IM /SRM motors
5. Battery cell and module- characterization
6. Battery Management System (BMS)
7. On-board and Off-board charger for EV
8. Study of Automotive Electronics-HVAC control, Steering Control, VCU; 2/3 or 4 Wheeler EV.

(or any other experiments based on EV/HEV related systems/ subsystems)

Use of software tools:

Use of tools like ADVISOR, MATLAB, SEMIKRON SEMISEL, Python, C, Java platforms (or similar) etc. for the following

1. Simulation/ Emulation of Vehicle performance analysis for Conventional and Electrical Vehicle
2. Design simulation of a battery pack with given specifications and constraints.

3. Simulation/ Emulation of BLDC motor drive for performance analysis
4. Simulation/ Emulation of PMSM motor drive for performance analysis
5. Simulation/ Emulation of IM motor drive for performance analysis
6. Simulation/ Emulation of SRM motor drive for performance analysis
7. Simulation/ Emulation of On board and Off board charger.
8. Simulation/ Emulation of regenerative breaking.

(or any other simulation based on EV/HEV related systems/ subsystems)

Visit to industrial/ manufacturing facility:

1. Visit to EV manufacturing facility.
2. Visit to Battery pack /BMS design facility
3. Visit to battery Charger facility
4. Visit to Automotive Research Association of India (ARAI), Pune EV COE

(or a visit to any facility / industry / research institute carrying out work in the domain of EV)

Course Project

Course project to be carried out to design /fabricate/ program one of the vehicular sub-systems used in EV

Note: Students and teachers are encouraged to use the virtual labs whose links are as given below. The remote-access to Labs in various disciplines of Science and Engineering is available. Students can conduct online experiments which would help them in learning basic and advanced concepts through remote experimentation.

Virtual Lab Website Reference

1. http://vlab.co.in/broad-area-electrical-engineering
2. https://www.vlab.co.in/broad-area-mechanical-engineering - Energy Storage Labs, Solar Energy lab, Wind Energy Lab

Term work:

Term work shall consist of minimum eight experiments, at least one plant visit, and one course project. The distribution of marks shall be as follows:

Experiments Performance	: 20 marks
Attendance	: 05 marks
Plant Visit report	: 10 marks
Course Project report	: 10 Marks
Journal & Attendance	: 10 marks

The final certification and acceptance of term work ensures the minimum passing in the term work.

Oral Examination:

Oral examination will be based on entire lab work of HCEVSBL701-Electric Vehicles Lab

'Electric Vehicle' - SEM-VIII						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Tutorial	Theory	Tutorial	Total
HCEV801	**Electric Vehicle System Design**	04	-	04	-	04

Course code	Course Name	Examination Scheme						
		Theory					Term Work	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)		
		Test 1	Test 2	Avg.				
HCEV801	**Electric Vehicle System Design**	20	20	20	80	03	-	100

Course Objectives	1. To illustrate the design philosophies used in the EV domain. 2. To explore the selection of power and control architecture of EV drives 3. To study the design aspects of EV battery packs and other auxiliary systems
Course Outcomes	Upon successful completion of this course, the learner will be able to: 1. To select and size the electric motor for a particular EV application and performance criteria 2. To select and size the battery pack to meet desired EV performance and 3. To design the EV drive system with functional safety considerations. 4. To illustrate the use of hybrid energy source for EV performance improvement 5. To illustrate the design aspects of Automotive Subsystem 6. To design the EV chargers and charging infrastructure

Module	Contents	Hours
1.	**Selection/ Sizing of EV Electric Motors:** Electric Vehicle modelling, Tractive force calculations, Design considerations for 2W, 3W and 4W EVs; Torque, power and Speed requirement, Traction Limit, Maximum Acceleration Limit, Maximum Grade Limit, Vehicle Power Demand Vehicle Performance Envelope, and Vehicle Power Envelope; Vehicle Power Demand during Driving Cycles. Design considerations for EV motors and their cooling system. Application Examples of EV /HEV motors with vehicles and motor specifications.	08
2.	**Selection/ Sizing of Battery pack and other Energy Resource:** Selection of type of Battery pack for 2W, 3W and 4W EVs; Battery pack sizing: Design considerations: Range per charge, range anxiety, EV motor power requirement; Impact of road conditions, environmental conditions and traffic conditions. High-Voltage Cabling and Disconnects, Safety in Battery Design, Testing for safety. Accelerated Reliability Testing of Electric Vehicles, Battery Cycle Life versus Peak Power and Rest Period. Selection and sizing of Fuel cell for FCEV, design considerations; Battery-ultra-capacitor hybrid combination sizing, performance analysis. Design considerations for Ultra-capacitor based EV, requirement of charging infra. Flywheel selection and sizing for EV/HEV applications.	12
3.	**Automotive Subsystem Design:** Electronic Control Unit (ECU) and its Control Features, Communications between ECUs, Control Software Development: Software-in-the-Loop (SIL) Simulation and Hardware-in-the-Loop (HIL) Simulation.	06

	Acceleration and braking control, regenerative braking; Automotive Steering Systems. Design considerations of HVAC controller	
4.	**EV System integration:** EMC design on ECU level, EMC design on system level and in special subsystems, Radiated emissions and Conducted emissions, EMI EMC measurements.	06
5.	**Design of Charging Infrastructure:** Design considerations for AC charger: vehicle interface and charging protocol design. applicable charging standards Design of On-Board Charger (OBC)-Schematic, power topology and control, Power capacities, regenerative braking control. Design considerations of DC fast charger: vehicle interface and charging protocol design. Connectivity and applicable charging standards Installation guidelines and grid requirement for charger installations.	12
6.	**Design with Functional Safety of Automotive Electronics:** Functional Safety requirements of Automotive Electronics; ASIL identification and safety goal finalization, ISO 26262. Energy Storage integrity / protection: rupture and toxic gas management; low energy stranding, Unintended vehicle movement, shock protection, and Elimination of potential thermal/ explosive event. Hazard and Risk Analysis (HARA) for different situations, Testing of vehicles for compliance of safety norms	08

Text/Reference Books:-

1. Design and Control of Automotive Propulsion Systems by Zongxuan Sun and Guoming Zhu, CRC Press, 2015
2. Electric Vehicle Machines And Drives Design, Analysis and Application by K. T. Chau, IEEE Press, and Wiley, 2015
3. EMC and Functional Safety of Automotive Electronics by Kai Borgeest, IET, 2018

Website Reference / Video Courses:

1. NPTEL Web Course: Electric Vehicles - Part 1 by PROF. AMIT KUMAR JAIN Department of Electrical Engineering IIT Delhi; https://nptel.ac.in/courses/108/102/108102121/
2. NPTEL Web Course: Fundamentals of Electric vehicles: Technology & Economics, by Prof. Ashok Jhunjhunwala, Prof. Prabhjot Kaur, Prof. Kaushal Kumar Jha and Prof. L Kannan, IIT Madras, https://nptel.ac.in/courses/108/106/108106170/
3. NPTEL Web Course: Introduction to Hybrid and Electric Vehicles by Dr. Praveen Kumar and Prof. S. Majhi, IIT Guwahati, https://nptel.ac.in/courses/108/103/108103009/

Assessment:

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Theory Examination:

1. Question paper will comprise of 6 questions, each carrying 20 marks.
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4. Remaining question will be randomly selected from all the modules.