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	Total	Credits
TE Sem V	**HEVC501: Vehicular Systems and Dynamics**	04	--	--	20	80	--	--	100	04
	Total	**04**	**-**	**--**	**100**		**-**	**-**	**100**	**04**
									Total Credits =	**04**
TE Sem. VI	**HEVC601: EV Drive and Energy Sources**	04	--	--	20	80	--	--	100	04
	Total	**04**	**-**	**-**	**100**		**-**	**-**	**100**	**04**
									Total Credits =	**04**
BE Sem. VII	**HEVC701: Automotive Controllers and Auxiliary Systems**	04	--	--	20	80	--	--	100	04
	HEVSBL701: Electric Vehicles Lab	--	--	04	--	--	50	50	100	02
	Total	**04**	**-**	**04**	**100**		**50**	**50**	**200**	**06**
									Total Credits =	**06**
BE Sem. VIII	**HEVC801: 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
HEVC601	**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.				
HEVC601	**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
HEVC701	**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.				
HEVC701	**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);	10

	In Vehicle communication system: CAN, LIN, Ethernet, Flexray	
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
HEVSBL701	**Electric Vehicles Lab**		04	--	02	02

Course code	Course Name				Examination Scheme				
		Theory					Term Work	Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)			
		Test 1	Test 2	Avg.					
HEVSBL701	**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:

Journal / Experiments Performance	: 25 marks
Attendance	: 05 marks
Plant Visit report	: 10 marks
Course Project report	: 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
HEVC801	**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.				
HEVC801	**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. Acceleration and braking control, regenerative braking; Automotive Steering Systems.	06

	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:

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.

University of Mumbai

Syllabus

Honours/Minor Degree Program

In

Microgrid Technology

FACULTY OF SCIENCE & TECHNOLOGY

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

University of Mumbai Microgrid Technology (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	Total	Credits
TE Sem V	**HMTC501: Futuristic Power Systems**	04	--	--	20	80	--	--	100	04
	Total	**04**	**-**	**--**	**100**		**-**	**-**	**100**	**04**
									Total Credits =	**04**
TE Sem. VI	**HMTC601: Power Electronic Converters for Energy Sources**	04	--	--	20	80	--	--	100	04
	Total	**04**	**-**	**-**	**100**		**-**	**-**	**100**	**04**
									Total Credits =	**04**
BE Sem. VII	**HMTC701: Microgrid Power and Control Architecture**	04	--	--	20	80	--	--	100	04
	HMTSBL701: Microgrid and RES Lab	--	--	04	--	--	50	50	100	02
	Total	**04**	**-**	**04**	**100**		**50**	**50**	**200**	**06**
									Total Credits =	**06**
BE Sem. VIII	**HMTC801: Microgrid 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										

'Microgrid Technology - SEM-V						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Tutorial	Theory	Tutorial	Total
HMTC501	**Futuristic Power 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.				
HMTC501	**Futuristic Power Systems**	20	20	20	80	03	-	100

Course Objectives	1. To explore the state of the art and future trends in power systems. 2. To understand the technical, economic and social challenges in power system evolution. 3. To realize the role and importance of Microgrids if futuristic power systems.
Course Outcomes	Upon successful completion of this course, the learner will be able: 1. To solicit the importance of large scale renewable energy integration with existing grid infrastructure. 2. To understand the importance and utility of Energy storage systems in futuristic power systems. 3. To explore large scale micro-grid deployment with RES and ESS integration. 4. To understand the role of communication and IT Infrastructure in power system and related challenges. 5. To explore the potential of Microgrids and its importance in Indian context.

Module	Contents	Hours
1.	**Introduction:** Present status of worldwide scenario of electricity generation, transmission and distribution; Energy infrastructure-Resilience and Security; Social, Technical and economic challenges; Major trends driving power system evolution; State of the art technologies in power system.	06
2.	**Renewable Energy Integration:** Review of renewable energy (RE) resources and systems: Solar- PV, Solar Thermal, Wind, Biomass, Micro-hydro and Fuel Cell, comparison of various RE resources; Renewable Energy Policies and present status of integration with existing grid; Large scale integration of renewable energy-Technical challenges, enabling technologies, International requirements; Renewable energy forecasting	12
3.	**Energy Storage Systems (ESS):** Review of energy storage components: Battery, VRB, Ultra-capacitor, Fuel Cells, Pumped Hydro-Storage and flywheels, comparison of ESS technologies; Importance of ESS in futuristic power systems; Aggregated ESS, Distributed ESS; Applications of ESS: Energy Management (Load Leveling and Peak Shifting), Fluctuation Suppression (Intermittency Mitigation), Uninterruptible Power System Low-Voltage Ride Through; Placement of the ESS to Improve Power Quality, Voltage Regulation Using ESS, ESS as Spinning Reserve.	12
4.	**Micro-grid and Smart-grid** Micro-grid evolution: Micro-grid concept, importance in futuristic power system, basic architectures and control, objectives and state of the art technologies; Microgrid as a building block of Smart-grid; Smart-grid concept, Smart Grid versus conventional electrical networks, Smart-grid infrastructure, Smart Grid communication system and its cyber security, International standard IEC 61850 and its application to Smart-grid;	12

	Microgrids /smart grid and Electric Vehicles integration. Technical, Economic, Environmental and Social Benefits of Microgrid Operation.	
5.	**Communication and IT infrastructure:** Requirements of Communication and IT infrastructure in futuristic power systems: various communication protocols, comparison of performance; IEEE standard: IEEE 802.11 Mesh Networking, IEEE 802.15.4-Wireless Sensor Networks; Communications Technologies for Smart metering; Cyber security issues and mitigation techniques.	05
6.	**Microgrids in India:** Microgrids for Rural Electrification, Review of Microgrid Best Practices through Case Studies: Strategic Planning, Operations: Commercial and Financial Considerations; Technical and Social Context.	05

Text Books:-

1. Microgrids Architectures and Control Edited by Nikos Hatziargyriou, IEEE and Wiley, 2014
2. Energy Storage for Sustainable Microgrid by David Wenzhong Gao, Elsevier, 2015
3. Introduction to the Smart Grid- Concepts, Technologies and Evolution by Salman K. Salman, IET, 2017
4. Energy Storage Systems and Components by Alfred Rufer, CRC Press, 2018

Reference Books:-

1. Energy Efficiency and Renewable Energy Handbook Edited by D. Yogi Goswami and Frank Kreith, 2nd Edition-2016, CRC
2. Clean Energy Microgrids, Edited by Shin'ya Obara and Jorge Morel IET, 2017
3. Hybrid-Renewable Energy Systems in Microgrids- Integration, Developments and Control edited by Hina Fathimaby *et al*., Elsevier WoodHead Publishing, 2018
4. Smart Microgrids: Lessons from Campus Microgrid Design and Implementation edited by Hassan Farhangi, CRC Press 2017

Website Reference / Video Courses:

1. NPTEL Web Course on: DC Microgrid And Control System Prof. Avik Bhattacharya, IIT Roorkee
2. NPTEL Web Course on Electronics and Distributed Generation Dr. Vinod John Department of Electrical Engineering IISc Bangalore
3. NPTEL Web Course on Introduction to Smart Grid, PROF. N.P. PADHY Department of Electrical Engineering IIT Roorkee PROF. PREMALATA JENA Department of Electrical Engineering
4. NPTEL Web Course on Electric vehicles and Renewable energy, Prof. Ashok Jhunjhunwala, Prof. Prabhjot Kaur, Prof. Kaushal Kumar Jha and Prof. L Kannan, IIT Madras

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.

'Microgrid Technology - SEM-VI						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Tutorial	Theory	Tutorial	Total
HMTC601	**Power Electronic Converters for 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.				
HMTC601	**Power Electronic Converters for Energy Sources**	20	20	20	80	03	-	100

Course Objectives	1. To illustrate the design philosophies used in the domain of microgrid power converters. 2. To explore the control implementations in power converters for voltage, current and power regulation for various DC and AC energy sources
Course Outcomes	Upon successful completion of this course, the learner will be able to: 1. Select and size various passive and active components for power converters 2. Design power converters used with DC energy resources with their control implementation 3. Design power converters used with AC energy resources with their control implementation 4. Understand the design considerations of power conditioning unit for ESS, SPV and Wind applications. 5. Understand the design and selection aspects of various auxiliary systems and components used in PCUs

Module	Contents	Hours
1.	**Selection of components for Power Electronics Converters (PEC):** Selection and Sizing of capacitors and magnetic components for PECs, design of Magnetic Components; Selection and sizing of Power Devices, Commonly used software tools for selection and sizing; Heatsink- selection and sizing.	06
2.	**Design and Control of DC-DC Converters:** Design of Buck and Boost converters, Design examples; Design of Bidirectional Converters. Design of gate driver circuits; Review of DC-DC converter modelling; Closed loop PI controller design for buck and boost converters; Current control mode and voltage control mode.	10
3.	**Design and Control of DC-AC converters:** Design of Inverter for standalone applications; Design of grid connected Inverter with different grid synchronization strategies- ZCD, PLL; Strategies for Control of voltage, current and power output.	10
4.	**Design of PCU for SPV and Wind Application:** Various topologies of Power Converter Unit (PCU) for SPV and Wind energy systems. Design considerations of PCU for SPV and Wind energy Systems and Design Examples.	10
5.	**Design of PCU for ESS Applications:** Design consideration for BDC converter based PCU for batteries and Ultra-capacitors.	08
6.	**Design of Auxiliary System and Interfaces:**	08

	Design of current and voltage sensor interfaces; Design considerations for auxiliary power supplies; Design of protection and snubber components: Introduction to Digital Signal Processors (DSP) and microcontroller interfaces	

Text Books:-

1. Microgrids Design and Implementation edited by Antonio Carlos Zambroni de Souza and Miguel Castilla, Springer, 2019
2. Power Electronic Converters for Microgrids by Suleiman M. Sharkh, Mohammad A. Abusara, Georgios I. Orfanoudakis Babar Hussain, IEEE and Wiley, 2014
3. Microgrids Architectures and Control Edited by Nikos Hatziargyriou, IEEE and Wiley, 2014
4. Energy Storage for Sustainable Microgrid by David Wenzhong Gao, Elsevier, 2015
5. Control Circuits In Power Electronics Practical Issues In Design And Implementation Edited by Miguel Castilla, IET, 2016
6. Control and Dynamics in Power Systems and Microgrids by Lingling Fan, CRC Press, 2017
7. Integrated Power Electronic Converters and Digital Control, by Ali Emadi, Alireza Khaligh, Zhong Nie, and Young Joo, Lee 2009, CRC Press.

Reference Books:-

1. Cooperative Synchronization in Distributed Microgrid Control by Ali Bidram, Vahidreza Nasirian Ali Davoudi, and Frank L. Lewis, Springer, 2017
2. Hybrid-Renewable Energy Systems in Microgrids- Integration, Developments and Control edited by Hina Fathimaby et al., Elseiver WoodHead Publishing, 2018
3. Smart Microgrids- Lessons from Campus Microgrid Design and Implementation edited by Hassan Farhangi, CRC Press 2017
4. Energy Storage Systems and Components by Alfred Rufer, CRC Press, 2018

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.

'Microgrid Technology - SEM-VII						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Tutorial	Theory	Tutorial	Total
HMTC701	**Microgrid Power and Control Architecture**	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.				
HMTC701	**Microgrid Power and Control Architecture**	20	20	20	80	03	-	100

Course Objectives	1. To study various power and control architectures adopted in DC and AC Microgrids. 2. To explore various control strategies used in power control 3. To take insight into operations stability and protection issues related to Microgrids
Course Outcomes	Upon successful completion of this course, the learner will be able to: 1. Understand various types Microgrids based on applications, power and control architecture. 2. Illustrate various power control strategies adopted in DC, AC and Hybrid Microgrids 3. Compare and contrast various control architectures used DC, AC and Hybrid Microgrids 4. Illustrate the various operational challenges in Microgrids 5. Comprehend the various aspects related to the stability in Microgrids 6. Understand the protection challenges in Microgrids along with various protection methods to overcome these challenges,

Module	Contents	Hours
1.	<u>Microgrid Power Architecture:</u> Types of Microgrid system, AC and DC and Hybrids Microgrids, Application based Suitability of Microgrid type; Review of power architecture of various Microgrids deployed world-wide. Comparison of various Microgrid power architectures.	08
2.	<u>AC Microgrid and Control Architecture:</u> Black-start operation, Grid Synchronisation- various Grid synchronization methods, Grid forming and grid following operations; Power Control- Real and reactive power control in AC Microgrid, simple droop control and other variants of droop control, Unit Power Flow Control, Feeder power flow control and Mixed mode control, source optimization; Centralized, decentralised, distributed and hierarchical control architecture, Local and system / supervisory level control strategies, Multi Agent System (MAS) Based Control; Control approaches used in AC Microgrids deployed worldwide. Microgrid standards IEEE 1547 series. Communication in AC Microgrids	12
3.	<u>DC Microgrid and Control Architecture:</u> Power sharing in DC Microgrids, source optimization; Control approaches: Centralized, decentralised, distributed and hierarchical control architecture. Control approaches used in hybrid Microgrids. Communication in DC/Hybrid Microgrids	08

4.	Operational Control in Microgrids: Energy management in Microgrids, coordinated control, load management, grid synchronisation and islanding, Anti-islanding schemes; Various Architectural and Operational Challenges in Microgrid, Optimal operation of Microgrids.	08
5.	Microgrid Stability Steady-state and dynamic stability in AC and DC Microgrids, Methods to improve the stability in Microgrids; introduction to small signal and large signal stability analysis in Microgrids.	06
6.	Protection in Microgrids Fault scenarios in DC and AC Microgrids, Protection in DC and AC Microgrids, adaptive protection, Fault current source (FCS) based protection; Protection challenges in islanded and autonomous modes of operation and ways to mitigate.	10

Text/Reference Books:-

1. Microgrids Design and Implementation edited by Antonio Carlos Zambroni de Souza and Miguel Castilla, Springer, 2019
2. Microgrids Architectures and Control Edited by Nikos Hatziargyriou, IEEE and Wiley, 2014
3. Cooperative Synchronization in Distributed Microgrid Control by Ali Bidram, Vahidreza Nasirian Ali Davoudi, and Frank L. Lewis, Springer, 2017
4. Control Circuits In Power Electronics Practical Issues In Design And Implementation Edited by Miguel Castilla, IET, 2016
5. Control and Dynamics in Power Systems and Microgrids by Lingling Fan, CRC Press, 2017
6. Hybrid-Renewable Energy Systems in Microgrids- Integration, Developments and Control edited by Hina Fathimaby et al., Elseiver WoodHead Publishing, 2018
7. Urban DC Microgrid Intelligent Control and Power Flow Optimization by Manuela Sechilariu and Fabrice Locment, 2016 Elsevier
8. Integrated Power Electronic Converters and Digital Control, by Ali Emadi, Alireza Khaligh, Zhong Nie, and Young Joo, Lee 2009, CRC Press.
9. Island Power Systems by Lukas Sigrist, Enrique Lobato, Francisco M. Echavarren Ignacio Egido, and Luis Rouco, CRC Press, 2016

Website Reference / Video Courses:

1. NPTEL Web Course on: DC Microgrid and Control System Prof. Avik Bhattacharya, IIT Roorkee
2. NPTEL Web Course on Electronics and Distributed Generation Dr. Vinod John Department of Electrical Engineering IISc Bangalore
3. NPTEL Web Course on Introduction to Smart Grid, PROF. N.P. PADHY Department of Electrical Engineering IIT Roorkee PROF. PREMALATA JENA Department of Electrical Engineering
4. NPTEL Web Course on Electric vehicles and Renewable energy, Prof. Ashok Jhunjhunwala, Prof. Prabhjot Kaur, Prof. Kaushal Kumar Jha and Prof. L Kannan, IIT Madras

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.

Microgrid Technology - SEM-VII						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Practical	Theory	Practical	Total
HMTSBL701	**Microgrid and RES Lab**	--	04	--	02	02

Course code	Course Name	Examination Scheme							
		Theory					Term Work	Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)			
		Test 1	Test 2	Avg.					
HMTSBL701	**Microgrid and RES Lab**	--	--	--	--	--	50	50	100

Course Objectives	1. To provide hands-on with power converters used in AC, DC Microgrids 2. To explore various control implementation incorporated in Microgrids in simulation or with hardware 3. To study various auxiliary systems commonly used in Microgrids.
Course Outcomes	Upon successful completion of this course, the learner will be able to: 1. Test the various power converters used AC, DC Microgrids 2. Illustrate various operational modes of power converters 3. Illustrate various operational modes of Microgrid. 4. Describe the working of various auxiliary system interfaces (communication / sensors) 5. Analyse the steady-state and transient behaviour of Microgrid 6. Demonstrate the design the Microgrid and its sub-systems.

Contents
Microgrid / RES Lab: Experimental Setups (Any Five of the following) 1. Testing of Power Conversion Unit for DC Microgrid 2. Testing of Power Conversion Unit for AC Microgrid 3. DC Microgrid: Power Sharing between the sources 4. AC Microgrid: Power Sharing between the sources 5. Grid Connected Inverter 6. Grid Forming Inverter 7. Grid Interactive Inverter 8. Solar MPPT Control 9. Islanding detection 10. Island mode of operation of DC or AC Microgrid 11. Data transfer through Microgrid Communication Interfaces 12. Standalone Microgrid operation 13. Voltage and current sensing circuits 14. DSP / Microcontroller interface circuits 15. DSP / Microcontroller programming for converter control. (or any other experiments based on Microgrid related systems/ subsystems) Use of software tools: (Any three of the following) Use of tools like MATLAB, Scilab, PSIM, LTSPice, python, C, Java platforms etc. for the following

1. Simulation/ Emulation of DC Microgrid with steady state performance analysis.
2. Simulation/ Emulation of AC Microgrid with steady state performance analysis.
3. Simulation/ Emulation of DC Microgrid ith transient performance analysis.
4. Simulation/ Emulation of AC Microgrid with transient performance analysis.
5. Microgrid Stability analysis with study of impact of ESS on stability

(or any other simulations based on Microgrid related systems/ subsystems)

Plant Visit:

Visit to existing Microgrid facility or a Solar PV/ Wind Installation or a power converters manufacturing / research facility.

Course Project

Course project to be carried out to design /fabricate/ program one of the PCU used in Microgrid.

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:

Journal / Experiments Performance	: 25 marks
Attendance	: 05 marks
Plant Visit report	: 10 marks
Course Project report	: 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 HCMTSBL701-Microgrid and RES Lab

'Microgrid Technology - SEM-VIII						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Tutorial	Theory	Tutorial	Total
HMTC801	**Microgrid 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.				
HMTC801	**Microgrid System Design**	20	20	20	80	03	-	100

Course Objectives	1. To illustrate the design philosophies used in the domain of Microgrid. 2. To explore the selection of power and control architecture of Microgrids 3. To study the design aspects of AC Microgrid, DC Microgrid and their auxiliary systems
Course Outcomes	Upon successful completion of this course, the learner will be able to: 1. Select and size various Microgrid energy resources 2. Select the power and control architecture of the Microgrid 3. Select and design the Microgrid's communication architecture. 4. Illustrate the design aspects DC Microgrids with their control strategies. 5. Illustrate the design aspects AC Microgrids with their control strategies. 6. Illustrate the implementation of the Microgrid islanding detection and anti-islanding scheme/ blackstart operation

Module	Contents	Hours
1.	**Selection/ Sizing of Microgrid Energy Resources** Factors affecting the selection and sizing of energy resources for Microgrid applications, dependency on type of loads connected, Selection/ Sizing: Renewable energy resources, Energy Storage components. Hybrid combination of RES and ESS.	07
2.	**Selection of Power and Control Architecture:** Factors affecting the selection of Microgrid power and control architecture; Design Consideration for control implementation; Sensors: Selection of sensors and design of sensor Interfaces, design of control Interfaces. Design considerations for DSP/ Microcontroller interfaces	07
3.	**Selection and Design of Communication Architecture** Design considerations for selection of communication network for Microgrid applications; Design and implementation of communication links/ interfaces. Microg4controller programming for Data transfer on communication network. Practical design considerations for Communication networks.	08
4.	**Design of DC Microgrid** Design DC Power Conditioning Units for RES and ESS, Unidirectional and Bidirectional Converter design, implementation of Control loop with DSP; Programming for Power sharing and Energy Management algorithms; Design of Protection system for DC Microgrid	12

5.	**Design of AC Microgrid** Design AC Power Conditioning Units for RES and ESS, Unidirectional and Bidirectional Converter design, implementation of Control loop with DSP; Grid Synchronization. Programming for Power sharing and Energy Management algorithms; Design of Protection system for AC Microgrid.	12
6.	**Islanding in Microgrids** Selection and implementation of Islanding detection and anti-islanding scheme; Black-start and Autonomous operations in Microgrids;	06

Text Books:-

1. Microgrids Design and Implementation edited by Antonio Carlos Zambroni de Souza and Miguel Castilla, Springer, 2019
2. Microgrids Architectures and Control Edited by Nikos Hatziargyriou, IEEE and Wiley, 2014
3. Power Electronic Converters For Microgrids by Suleiman M. Sharkh, Mohammad A. Abusara, Georgios I. Orfanoudakis Babar Hussain, IEEE and Wiley, 2014

Reference Books:-

1. Energy Storage for Sustainable Microgrid by David Wenzhong Gao, Elsevier, 2015
2. Cooperative Synchronization in Distributed Microgrid Control by Ali Bidram, Vahidreza Nasirian Ali Davoudi, and Frank L. Lewis, Springer, 2017
3. Energy Efficiency and Renewable Energy Handbook Edited by D. Yogi Goswami and Frank Kreith, 2nd Edition-2016, CRC
4. Control Circuits In Power Electronics Practical Issues In Design And Implementation Edited by Miguel Castilla, IET, 2016
5. Hybrid-Renewable Energy Systems in Microgrids- Integration, Developments and Control edited by Hina Fathimaby et al., Elseiver WoodHead Publishing, 2018
6. Urban DC Microgrid Intelligent Control and Power Flow Optimization by Manuela Sechilariu and Fabrice Locment, 2016 Elsevier
7. Integrated Power Electronic Converters and Digital Control, by Ali Emadi, Alireza Khaligh, Zhong Nie, and Young Joo, Lee 2009, CRC Press.

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.

University of Mumbai

Syllabus

Honours/Minor Degree Program

In

Robotics

FACULTY OF SCIENCE & TECHNOLOGY

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

University of Mumbai Robotics (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	Total	Credits
TE Sem V	**HRBC501: Industrial Robotics**	04	--	--	20	80	--	--	100	04
	Total	04	-	--	100		-	-	100	04
Total Credits = 04										
TE Sem VI	**HRBC601: Mechatronics &IoT**	04	--	--	20	80	--	--	100	04
	Total	04	-	-	100		-	-	100	04
Total Credits = 04										
BE Sem VII	**HRBC701: Artificial Intelligence & Data Analysis**	04	--	--	20	80	--	--	100	04
	HRBSBL701: Robotics and Automation Lab	--	--	04	--	--	50	50	100	02
	Total	04	-	04	100		50	50	200	06
Total Credits = 06										
BE Sem VIII	**HRBC801: Autonomous Vehicle**	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										

Robotics - SEM-VI		
Course Code	Course Name	Credits
HRBC501	**Industrial Robotics**	4

Course Objectives:

1. To acquaint with significance of robotic system in agile and automated manufacturingprocesses.
2. To make conversant with robotic elements/ peripherals, their selection and interface with manufacturing equipment's.
3. To study the basics of robot kinematics

Course Outcomes: Upon successful completion the course, learner will be able to

1. Acquire skills in understanding robot language and programming.
2. Acquire skill in robot task planning for problem solving.
3. Develop skills in understanding various sensors, robot peripherals and their use & deployment in manufacturing system.
4. Develop skills in identifying areas in manufacturing where robotics can be deployedfor enhancing productivity.

Module	Details	Hours
1.	Introduction Automation, robotics, Robotic system & Anatomy,Classification and Future Prospects	2
2.	**Drives** Control Loops, Basic Control System Concepts & Models, Control System Analysis, Robot Activation & Feedback Components, Position & Velocity Sensors, Actuators and Power Transmission system. **Robot & its Peripherals** **End Effecters:** Type mechanical and other grippers, Tool as end effecter. **Sensors:** Sensors in Robotics, Tactile Sensors, Proximity & Range Sensors, Sensor Based Systems, Vision systems and Equipment	10
3.	**Machine vision** Introduction, Low level & High level Vision, Sensing & Digitizing, Image Processing & analysis, Segmentation, Edge detection, Object Description & recognition, interpretationand Applications. **Programming for Robots** Method, Robot Programme as a path in space, Motion interpolation, motion & task level Languages, Robot languages, Programming in suitable languages and characteristics ofrobot.	10
4.	**Robot Kinematics** Forward, reverse & Homogeneous Transformations, Manipulator Path control and Robot Dynamics. **Introduction to wheeled and legged robots including humanoids**	10
5.	**Robot Intelligence & Task Planning** Introduction, State space search, Problem reduction, use of predictive logic, Means. Ends Analysis, Problem solving, Robot learning and Robot task planning.	10

6.	**Robot application in manufacturing Material transfer, machine loading & un loading, processing operation, Assembly & inspectors, robotic Cell design & control, Social issues & Economics of Robotics.**	10

Assessment:

Internal Assessment for 20 marks:

Consisting **Two Compulsory Class Tests**

First test based on approximately 40% of contents and second test based on remaining contents (approximately 40% but excluding contents covered in Test I)

End Semester Examination:

1. Weightage of each module in end semester examination will be proportional to the numberof respective lecture hours mentioned in the curriculum.
2. Question paper will comprise of total six questions, each carrying 20 marks
3. Question 1 will be compulsory and should cover maximum contents of the curriculum
4. Remaining questions will be mixed in nature (for example if Q.2 has part (a) from module 3then part (b) will be from any module other than module 3)
5. Only four questions need to be solved

Text/References

1. Industrial Robotics, Technology, Programming & Applications, Grover, Weiss, Nagel, Ordey,Mc Graw Hill.
2. Robotics: Control, Sensing, Vision & Intelligence, Fu, Gonzalex, Lee, Mc Graw Hill.
3. Robotic technology & Flexible Automation, S R Deb. TMH.
4. Robotics for Engineers, Yoram Koren , Mc Graw hill.
5. Fundamentals of Robotics, Larry Health.
6. Robot Analysis & Control, H Asada, JJE Slotine.
7. Robot Technology, Ed. A Pugh, Peter Peregrinus Ltd. IEE, UK. 8. Handbook of IndustrialRobotics, Ed. Shimon. John Wiley
8. Roland Siegwart, Illah Reza Nourbakhsh, and Davide Scaramuzza, “Introduction to AutonomousMobile Robots”, Bradford Company Scituate, USA

Robotics - SEM-VI		
Course Code	**Course Name**	**Credits**
HRBC601	**Mechatronics & IoT**	**4**

Course Objectives:

1. To associate a mechatronic System with IOT
2. To relate data analytics with IOT
3. To understand Cloud Computing in IOT

Course Outcomes: Upon successful completion of this course, the learner will be able to

1. Describe a Mechatronic System
2. Demonstrate the use of a Micro-controller
3. Understand an IOT System
4. Identify Wireless Technologies Supporting IOT
5. Use Data Analytics in conjunction with IOT &Cloud

Module	Details	Hours
1.	Introduction to Mechatronics: Traditional and Mechatronics Design, Mechatronics Key Elements, Basic Components of Mechatronic Systems , Integrated Design issues in Mechatronics, Mechatronics Design Process, Mechatronics System in Factory, Home and Business Applications, Objectives, Advantages and Disadvantages of Mechatronics	6
2.	Overview of Micro-processor ad Micro-controller: 8051 Micro-controllers, Functional Block Diagram and Architecture, Instruction set and Assembly Language Programming, Analog and Data Acquisition , Digital I/O interfacing, Special Function interfacing, Signal Conditioning, Special Utility Support hardware Interfacing of HEX – Keyboards, LCD Display, ADC, DAC andStepper Motor with 8051 Micro-controller	10
3.	Introduction and application to Internet of Things: Need of IoT, history of IOT, Objects of IOT, Level of IOT, Technologies in IOT, Introduction to Arduino and Raspberry Pi, understanding its components, recognizing the Input/Output, GPIO Connectivity	10
4.	Wireless Technologies Supporting IoT: Protocol Standardization for IoT, Machine to machine (M2M) and WSN protocols, Basics of RFID , RFID Protocols, Issues with IOT Saudization, Protocols – IEEE 802.15.4, Zigbee, IPv6 Technologies for IOT	10
5.	Data Analytics for IOT: Introduction Apache Hadoop, Using Hadoop MapReduce for Batch Data Analysis, Apache Oozie, Apache Spark, Apache Storm, Using Apache Storm for Real Tie Data Analysis, Structural Health Monitoring, Case Study: Chef Case Study, puppet Case Study	10
6.	Introduction to Cloud Computing, Difference between Cloud Computing and FOG Computing: The Next Evolution of Cloud Computing, Role of Cloud Computing in IOT, Connecting IoT to Cloud, Cloud Storage for IoT Challenge in Integration of IoT with Cloud	8

Assessment:

Internal Assessment for 20 marks:

Consisting **Two Compulsory Class Tests**

First test based on approximately 40% of contents and second test based on remaining contents (approximately 40% but excluding contents covered in Test I)

End Semester Examination:

1. Weightage of each module in end semester examination will be proportional to the numberof respective lecture hours mentioned in the curriculum.
2. Question paper will comprise of total six questions, each carrying 20 marks
3. Question 1 will be compulsory and should cover maximum contents of the curriculum
4. Remaining questions will be mixed in nature (for example if Q.2 has part (a) from module 3then part (b) will be from any module other than module 3)
5. Only four questions need to be solved

Text/Reference Books:

1. Bolton, William. Mechatronics: electronic control systems in mechanical and electricalengineering. Pearson Education, 2003.
2. De Silva, Clarence W. Mechatronics: an integrated approach. CRC press, 2004.
3. Ayala, Kenneth J. The 8051 microcontrollers. Thomson Delmar Learning, 2005.
4. Zhang, Dan, and Bin Wei, eds. Mechatronics and Robotics Engineering for Advanced andIntelligent Manufacturing. Springer International Publishing, 2017.
5. Greengard, Samuel. The internet of things. MIT press, 2021.
6. Chaouchi, Hakima, ed. The internet of things: Connecting objects to the web. John Wiley &Sons, 2013.
7. Hintz, Kenneth, and Daniel Tabak. Microcontrollers: architecture, implementation, andprogramming. McGraw-Hill, Inc., 1992.

Robotics - SEM-VII		
Course Code	**Course Name**	**Credits**
HRBC701	**Artificial Intelligence andData Analytics**	**04**

Course Objectives:

1. To gain perspective of AI, its foundations, agent architectures and properties of theenvironment.
2. To understand the basic principles of AI towards problem solving, inference, perception,knowledge representation, and learning.
3. To investigate probabilistic reasoning under uncertain and incomplete information.
4. To gain the perspective of the concepts of data Mining, modelling and visualization, data warehousing.
5. To understand various machine learning algorithms.

Course Outcomes: Upon successfully completion of this course, learner will able to...

1. Demonstrate knowledge of the building blocks of AI, intelligent agents and knowledgepresentation systems.
2. Explain artificial intelligence planning, reasoning, uncertainty handing and expert systems.
3. Describe the concept of data mining, big data, data analytics, business intelligence.
4. Comprehend and implement data mining and machine learning algorithms.

Module	Contents	Hours.
01	**Introduction to Artificial Intelligence (AI):** A. I. Representation, Representation of knowledge, knowledge base systems, state space search, production systems, problem characteristics, types of production systems, Intelligent Agents and Environments, nature of environments, structure of agents **Knowledge and Reasoning:** Knowledge Representation Systems, Properties of Knowledge Representation Systems, Propositional Logic (PL), First Order Logic: Syntax and Semantic, Inference in FOL, Forward v/s Backward Chaining	**6**
02	**Planning:** Introduction to Planning, Planning with State Space Search, Partial Ordered planning, Hierarchical Planning, Conditional Planning, Brief introduction to single layer and multiplayer networks **Reasoning Under Uncertainty:** Handling Uncertain Knowledge, Random Variables, Prior and Posterior Probability, Inference using Full Joint Distribution, Bayes' Rule and its use, Bayesian Belief Networks, Reasoning in Belief Networks **Introduction to Expert Systems:** Components of Expert System: Knowledge base, Inference engine, user interface, workingmemory, Development of Expert Systems	**10**

03	**Introduction to Data Mining:** What is Data Mining; Kind of patterns to be mined; Technologies used; Major issues in Data Mining, associative Rule Mining **Introduction to Big Data:** Big Data characteristics, types of Big Data, Traditional vs. Big Data business approach, Case Studies ofBig Data Solutions, Introduction to parallel Processing (MPP) architecture, Hadoop/HDFS and cloud based solutions **Introduction to Business Intelligence:** Business intelligence (BI): Managers and Decision Making, BI for Data analysis and Presenting Results	**8**
04	**Data Pre-processing:** Notion of data quality. Typical pre-processing operations: combining values into one, handling incomplete/ incorrect / missing values, recoding values, sub setting, sorting, transforming scale, determining percentiles, removing noise, removing inconsistencies, transformations, standardizing, normalizing - min-max normalization, z-score standardization. **Data Modeling and visualization:** Logic driven modeling, data driven modeling, basic what-if spreadsheet models **Data Warehousing:** What is a data warehouse, need for a data warehouse, architecture, data marts, OLTP vs OLAP	**10**
05	**Machine Learning:** Supervised and Unsupervised Learning, Concepts of Classification, Clustering and prediction **Performance Measures:** Measuring Quality of model- ConfusionMatrix, Accuracy, Recall, Precision, Specificity, F1 Score, RMSE	**8**
06	**Classification:** Rule based classification, classification by BayesianBelief networks, Hidden Markov Models. **Clustering:** Hebbian Learning rule, Expectation -Maximizationalgorithm for clustering **Dimensionality Reduction:** Principal Component Analysis FeatureSelection and Feature Extraction **Time Series Analysis and Forecasting:** Time series patterns,forecast accuracy, moving averages and exponential smoothing	**10**

Assessment:

Internal Assessment for 20 marks:

Consisting **Two Compulsory Class Tests**

First test based on approximately 40% of contents and second test based on remaining contents (approximately 40% but excluding contents covered in Test I)

End Semester Examination:

1. Weightage of each module in end semester examination will be proportional to the numberof

respective lecture hours mentioned in the curriculum.

2. Question paper will comprise of total six questions, each carrying 20 marks
3. Question 1 will be compulsory and should cover maximum contents of the curriculum
4. Remaining questions will be mixed in nature (for example if Q.2 has part (a) from module 3then part (b) will be from any module other than module 3)
5. Only four questions need to be solved

Text Books:

1. Stuart J. Russell and Peter Norvig, "Artificial Intelligence A Modern Approach —SecondEdition" Pearson Education.
2. Elaine Rich and Kevin Knight —Artificial Intelligence‖ Third Edition, Tata McGraw-HillEducation Pvt. Ltd., 2008.
3. George F Luger "Artificial Intelligence" Low Price Edition, Pearson Education, Fourth edition.
4. Deepak Khemani, A first course in Artificial Intelligence, Mc GrawHill
5. P. N. Tan, M. Steinbach, Vipin Kumar, "Introduction to Data Mining", Pearson Education.
6. G. Shmueli, N.R. Patel, P.C. Bruce, "Data Mining for Business Intelligence: Concepts, Techniques, and Applications in Microsoft Office Excel with XLMiner", 2nd Edition, Wiley India.
7. Ethem Alpaydın, "Introduction to Machine Learning", MIT Press
8. Peter Flach, "Machine Learning", Cambridge University Press

Reference Books:

1. Tom M. Mitchell, "Machine Learning", McGraw Hill
2. Kevin P. Murphy, "Machine Learning — A Probabilistic Perspective", MIT Press
3. Stephen Marsland, "Machine Learning an Algorithmic Perspective", CRC Press
4. Shai Shalev-Shwartz, Shai Ben-David, "Understanding Machine Learning", CambridgeUniversity Press
5. Peter Harrington, "Machine Learning in Action", DreamTech Press
6. D. W. Patterson, Artificial Intelligence and Expert Systems, Prentice Hall.
7. Saroj Kaushik "Artificial Intelligence", Cengage Learning.

Links for online NPTEL/SWAYAM courses:

https://onlinecourses.nptel.ac.in/noc19_me71/previewhttps://onlinecourses.nptel.ac.in/noc22_cs56/preview

https://onlinecourses.nptel.ac.in/noc22_cs29/preview https://onlinecourses.nptel.ac.in/noc22_cs08/preview

Robotics - SEM-VII		
Course Code	**Course Name**	**Credits**
HRBSBL701	**Robotics and Automation Lab**	**2**

Course Objectives:

1. To learn the implementation of image processing algorithms.
2. To acquaint with programming of robots.
3. To acquaint with data acquisition over cloud environment
4. To demonstrate the working of machine learning algorithms for data prediction.

Course Outcomes: learner will able to...

1. Develop simple image processing algorithms.
2. Program robots for simple and inverse kinematics and trajectory planning.
3. Acquire sensor data over cloud using microcontroller.
4. Perform predictive data analysis using clustering, classification and regression models.

List of Experiments:

1. Edge detection / segmentation using image processing
2. programming the robots to solve direct and inverse kinematics problems
3. Trajectory planning for Robots
4. Acquisition of sensor data over cloud using microcontroller
5. Implementation of Clustering algorithm (K-means / K-medoids)
6. Data Classification using data prediction tool (classification tree / artificial neural networks,Support Vector Machines etc.) (Any One)
7. Linear Regression using data predictive tool (multiple regression / artificial neural networksetc.) (Any One)
8. PLC to operate actuators for automation application

Assessment:

Term Work

Term work shall consist of the experiments as mentioned above.The distribution of marks for term work shall be as follows:

1. Laboratory work (Experiments): 40 marks
2. Attendance: 10 marks

Oral Examination:

Oral examination will be based on entire lab work of **Robotics and Automation Lab**

Robotics - SEM-VIII		
Course Code	**Course Name**	**Credits**
HRBC801	**Autonomous Vehicle Systems**	**4**

Course Objectives:

1. To comprehend fundamental aspects of Autonomous Vehicles.
2. To Acquire knowledge of levels of automation of autonomous systems.
3. To Understand the Connectivity Aspects of autonomous automobiles

Course Outcomes: The student will be able to

1. Gain perspective of autonomous systems
2. Understand Automotive Electronics and the operation of ECUs.
3. Discuss about the use of computer vision and learning algorithms in vehicles.
4. Learn Localization, Perception, Prediction planning and control.
5. Summarize the aspects of connectivity
6. Understand cloud platform and ROS.

Module	Details	Hours
1	**An over view of autonomous driving technologies**: Algorithms, client systems, cloud Platforms	6
2	**Overview of Automotive Electronics**: Control Systems for Autonomous vehicles, Electronic Engine control, Chassis and Powertrain Electronics, Vehicle motion control, Instrumentation andTelematics & ADAS	8
3	**Sensing Technologies** Radar & Sonar, Camera, Lidar, GNSS.GPS/IMU Use of Sensor Data, Sensor Fusion and Kalman Filters	8
4	**Computer Vision and Deep Learning** Computer Vision Fundamentals -Advanced Computer Vision , Neural Networks for Image Processing , TensorFlow ,Convolutional Neural Networks	10
5	**Levels of Automation** Localization - GNSS, LiDAR, Wheel and Visual Odometry, sensorfusion Perception – Detection and Tracking, DrivingPerception and deeplearning Prediction and Routing- Trffic prediction and Lane level routing Decision, Planning and Control- Motion Planning,Feed back control Cloud System- Operating systems-ROS, Cloud Platforms	12
6	**Connected Car Technology:** Connectivity Fundamentals - DSRC (Direct Short Range Communication), Connectivity types -Vehicle-to-Vehicle, Vehicle-to-Roadside and Vehicle-to-Infrastructure, Vehicle-to-pedestrian, Vehicle- to-clous, Vehicle-to-everything, Applications -Security Issues Technical Issues, Security Issues, Moral and Legal Issues.	8

Text Books:

1. Shaoshan Liu, Liyun Li, “Creating Autonomous Vehicle Systems”, Morgan and Claypool Publishers,2017.
2. Liu, Shaoshan. Engineering autonomous vehicles and robots: the DragonFly modular-based approach. John Wiley & Sons, 2020.
3. Hong Cheng, “Autonomous Intelligent Vehicles: Theory, Algorithms and Implementation”, Springer,2011.
4. Williams. B. Ribbens: “Understanding Automotive Electronics”, 7th Edition, Elsevier Inc,2012.

Reference Books:

1. Marcus Maurer, J.Christian Gerdes, “Autonomous Driving: Technical, Legal andSocial Aspects”Springer, 2016.
2. Ronald.K.Jurgen, “Autonomous Vehicles for Safer Driving”, SAE International, 2013.
3. James Anderson, KalraNidhi, Karlyn Stanly, “Autonomous Vehicle Technology:A Guide forPolicymakers”, Rand Co, 2014.
4. Lawrence. D. Burns, Chrostopher Shulgan, “Autonomy – The quest to build thedriverless car andhow it will reshape our world”, Harper Collins Publishers, 2018

University of Mumbai

Syllabus

Honours/Minor Degree Program

In

3D Printing

FACULTY OF SCIENCE & TECHNOLOGY

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

University of Mumbai
3D Printing
(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	Total	Credits
TE Sem V	**H3DPC501: Introduction to CAD**	04	--	--	20	80	--	--	100	04
	Total	**04**	**-**	**--**	**100**		**-**	**-**	**100**	**04**
									Total Credits = 04	
TE Sem. VI	**H3DPC601: 3D Printing: Introduction & Processes**	04	--	--	20	80	--	--	100	04
	Total	**04**	**-**	**-**	**100**		**-**	**-**	**100**	**04**
									Total Credits = 04	
BE Sem. VII	**H3DPC701: Applications of 3D Printing**	04	--	--	20	80	--	--	100	04
	H3DPSBL701: Skill Based Lab – Digital Fabrication	--	--	04	--	--	50	50	100	02
	Total	**04**	**-**	**04**	**100**		**50**	**50**	**200**	**06**
									Total Credits = 06	
BE Sem. VIII	**H3DPC801: 3D Printing in Medical Technology**	04	-	--	20	80	--	--	100	04
	Total	**04**	**-**	**-**	**100**		**-**	**-**	**100**	**04**
									Total Credits = 04	
									Total Credits for Semesters V, VI, VII &VIII = 04+04+04+06 = 18	

'3D Printing':SEM-V						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Tutorial	Theory	Tutorial	Total
H3DPC501	**Introduction to CAD**	**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.				
H3DPC501	**Introduction to CAD**	**20**	**20**	**20**	**80**	**03**	**-**	**100**

Course Objectives	1. To impart the 3D modelling skills for development of 3D models of basic engineering components. 2. To familiarize with basic concepts of computer graphics. 3. To familiarize with basic concepts of additive and subtractive manufacturing process.
Course Outcomes	**Upon successful completion of this course, the learner will be able:** 1. Illustrate basic understanding of design. 2. Create the CAM Toolpath for specific given operations. 3. Illustrate basic understanding of types of CAD model creation. 4. Generate assembly models of given objects using assembly tools of a modelling software. 5. Identify suitable computer graphics techniques for 3D modelling. 6. Transform, manipulate objects & store and manage data.

Module	Contents	Hours
1.	**Design thinking:** Identification of need, Embodiment of design, Generation of ideas and research topics	5
2.	**Subtractive Manufacturing:** Introduction to NC/CNC/DNC machines **Additive Manufacturing:** Introduction to 3D Printing, Limitations of Subtractive manufacturing, Digital fabrication	8
3.	**CAD Introduction:** History & Scope of CAD, CAD hardware and software, Advantages, Disadvantages and Applications of CAD	7
4.	**Introduction to 2D modelling:** CAD models Creation, Types and uses of models from different perspectives **Introduction to assembly drawing:** Types of assembly drawings, part drawings, drawings for catalogues and instruction manuals, patent drawings, drawing standards	12

5.	**Computer Graphics:** Overview of 2D and 3D Computer Graphics, Parametric representation of curves: Synthetic Curves - Bezier curves, Hermite Curves, B-spline curves **Geometric Modelling:** Wire Frame Modelling, Solid Modelling, Surface Modelling, Parametric Modelling, Feature based Modelling, Constraint Based Modelling.	12
6.	**Geometric Transformation:** 2D & 3D Transformations (Translation, Rotation, & Scaling & Reflection), Concatenations	8

Text/Reference Books:-

1. Machine Drawing by N.D. Bhatt.
2. A textbook of Machine Drawing by Laxminarayan and M.L.Mathur, Jain brothers Delhi
3. CAD/ CAM, Theory & Practice, Ibrahim Zeid, R. Sivasubramanian, Tata McGraw Hill Publications
4. CAD/CAM Principles and Applications, P. N. Rao, Tata McGraw Hill Publications
5. CAD/CAM Computer Aided and Manufacturing, Mikell P. Groover and Emory W. Zimmers, Jr., Eastern Economy Edition
6. CNC Technology and Programming, Krar, S., and Gill, A., McGraw Hill Publishers.
7. Medical Modelling The Application of Advanced Design and Rapid Prototyping Techniques in Medicine, Richard Bibb, Dominic Eggbeer and Abby Paterson, Woodhead Publishing Series in Biomaterials: Number 91, Elsevier Ltd.
8. Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing, I. Gibson l D. W. Rosen l B. Stucker, Springer Publication.

Website Reference / Video Courses:

1. https://nptel.ac.in/courses/112/102/112102101/
2. https://nptel.ac.in/courses/106/102/106102065/
3. https://nptel.ac.in/courses/106/102/106102065/
4. https://nptel.ac.in/courses/112/102/112102103/
5. https://nptel.ac.in/courses/112/105/112105211/
6. https://nptel.ac.in/courses/112/104/112104265/
7. https://www.youtube.com/watch?v=2cCMty9v3Tg
8. https://www.youtube.com/watch?v=2zPh26Q1BT8

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.