COEP Technological University Pune

(A Unitary Public University of Govt. of Maharashtra)

School of Engineering and Technology

Curriculum Structure with Evaluation Scheme

Second, Third and Final Year B. Tech. in

Electrical Engineering

(S.Y. Structure Effective from: A.Y. 2024-25)
(T.Y. Structure Effective from: A.Y. 2025-26)
(Final Year Structure Effective from: A.Y. 2026-27)

Curriculum and structure of F.Y. and S.Y. B. Tech. in Electrical Engineering

Program Educational Objectives (PEOs)

After the completion of the program

I. Student will be employable in the diversified sectors of the industry, government organizations, public sector and research organizations.

II. Student will pursue higher education in electrical engineering or other fields of their interests, at institutes of repute and high ranking.

III. Student will demonstrate effective communication, life long learning ability, integrity, team work, leadership qualities, concern to environment and commitment tosafety, health, legal and cultural issues in the fields they choose to pursue.

Program Outcomes (POs):

Engineering Graduate will be able to:

PO1: Engineering Knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problem.

PO2: Problem Analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural science, and engineering sciences.

PO3: Design/Development Solution: Design solution for complex engineering problems and design system component or process that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, social and environmental conditions.

PO4: Conduct Investigation of Complex Problem: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data and synthesis of the information to provide valid conclusion.

PO5: Method, Tool Usage: Create, select and apply appropriately technique, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with understanding the limitation.

PO6: The Engineer and Society: Apply reasoning informed by the contextual knowledge to access societal health, safety, legal and cultural and consequent responsibility relevantto the professional engineering practice.

PO7: Environment and Sustainability: Understand the impact of the professional engineering solution in societal and environmental context, and demonstrate the knowledge of, and need for sustainable development.

PO8: Ethics: Apply ethical principle and commitment to professional ethics and responsibilities and norms of the engineering practices.

PO9: Individual and Team Work: Function effectively as an individual, and as the member or leader n diverse team and multidisciplinary setting.

PO10: Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, and being able to comprehend and write effective reports and design documentation and effective presentation and give and receive clear instructions.

PO11: Project management and Finance: Demonstrate knowledge & understanding of the engineering and management principles and apply these to ones work, as the member and the leader in a team to manage projects and in multidisciplinary environment.

PO12: Life Long Learning: Recognize the need for, and have the preparation and ability to engage in independent and lifelong learning in broadest context of technological change.

Program Specific Outcome for Undergraduate (PSOs):

PSO13: To design and develop power electronics hardware and its control to cater the needs of industry such as electric vehicles, renewable interconnections, smart grid and micro-grid.

PSO14: To analyze and solve the problems related to smart grid using modern techniques and tools.

PSO15: To design, simulate, and make prototype of special purpose machines for enhancing the Performance.

List of Abbreviations

Abbreviation	Title
BS	Basic Science Course
ESC	Engineering Science Course
PCC	Programme Core Course (PCC)
PEC	Programme Elective Course (PEC)
OE/SE	Open/School Elective (OE/SE) other than particular program
MD M	Multidisciplinary Minor (MD M)
VSEC	Vocational and Skill Enhancement Course (VSEC)
HSMC	Humanities Social Science and Management
IKS	Indian Knowledge System (IKS)
VEC	Value Education Course (VEC)
RM	Research Methodology (RM)
--	Internship
--	Project
CEA	Community Engagement Activity (CEA)/Field Project
CCA	Co-curricular & Extracurricular Activities (CCA)

Exit Option AFTER FIRST YEAR

To qualify for Certification, Common at the School Level

Note: Exiting students need to take one SEC from his/her discipline and the other of his/her choice.

[VSEC-] Instrumentation Workshop

Teaching Scheme
Theory: 28 hrs
Practical: 17 hrs

Examination Scheme
Test and hands on practice - 100 Marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to

1. Describe working principles of various transducers/sensors
2. Interpret the characteristics of the transducers/sensors
3. List various standards used for selection of transducers/sensors
4. Select transducers/sensors for specific applications
5. Examine the operation of the final control elements, pneumatic and hydraulic components generally used in plants

Unit1 **(7 hrs)**

Temperature: Temperature scales, classification of temperature sensors, standards, working principle, types, materials, Non electrical sensors (thermometer, thermostat), electrical sensors (RTD, thermocouple, thermistor)

Unit 2 **(7 hrs)**

Pressure and Level: Definition, pressure scale, standards, working principle, types, materials, elastic pressure sensors, secondary pressure sensors, differential pressure sensors, capacitive (delta cell), high-pressure sensors, low-pressure sensors, Standards, working principle, types, materials, design criterion: float, displacers, bubbler, ultrasonic, microwave, radar, resistance, thermal, solid level detectors.

Unit 3 **(7 hrs)**

Flow: Standards, working principle, types, materials, and design criterion: primary or quantity meters (positive displacement flow meter), secondary or rate meter (obstruction type, variable area type), electrical flow sensors (turbine type, electromagnetic type, and ultrasonic type), Flow switches

Unit 4 **(7 hrs)**

Actuators and accessories: Operation of control valve, Classification of control valves, Pneumatic Supply and its components: Filter Regulator Lubricator (FRL), Single acting & Double acting cylinder, Special cylinders, Operation of Direction Control valves, Types of pilot signal, operation of speed regulators, pressure control valve, Special valves like quick exhaust, pressure, time delay valve, Standard Symbols for pneumatic components, Hydraulic supply: reservoir, Types of filters, Function of accumulators, Hydraulic Actuators, Operation of Direction Control Valve, Standard symbols for hydraulic components

Textbooks:

- A. K. Sawhney, "Electrical and Electronic Measurements and Instrumentation", DhanpatRai and Sons, 12th ed., 2005.
- B. C. Nakra and K. K. Choudhari, "Instrumentation Measurements and Analysis" by, Tata McGraw Hill Education, 4th ed., 2016.
- Pneumatic Instrumentation by Majumdhar, TMH
- D.V.S. Murthi, "Instrumentation and Measurement Principles", PHI, New Delhi, Second

ed. 2003.

Reference Books:

- E.O. Doebelin, "Measurement Systems", McGraw Hill, 6th ed., 2017.
- D. Patranabis, "Principle of Industrial Instrumentation", Tata McGraw Hill, 2nd ed., 1999.
- Control Valve Handbook, Fisher Controls International, Inc. third Edition, 2001

List of Experiments:

- Measure inner and outer diameter of pipe using vernier calipers & compare it with standards.
- Measure thickness of the metallic sheet with micrometer & compare it with standards.
- Identify different electronic components viz. Resistor, Capacitor, Inductor, transformer, fuse, diode, transistor.
- Identify various resistors tyopes andMeasure value of given resistor & compare it with theoretical value obtained using colour code.
- Identify various capacitors viz paper , silvered paper, mica, silvered mica, ceramic plastic foil,electrolytic
- Identify various inductors viz fixed and variable inductors.
- Identify Piezo electric crystal & study it's application
- Wire instrument panel with various accessories as per instrument hook-up diagram.
- Wire the MCB, ELCB to supply electrical power to instrument panel.
- Wire the MCB, ELCB, contactor, starter to supply electrical power to motor drive panel as per given wiring diagram for one application.
- Dismantle & assemble valve to identify it's components as per sketch .
- Dismantle, assemble & calibrate pressure gauge.
- Install any one instrument using screw type connection and flange type connection.
- Test pressure/flow/level/temperature switch.
- Study and operate mechanical switches, and electromechanical switches.
- Study and operate special components like DCVs, FRL, flow control valves, pressure regulating valve, exhaust valve, displays, relays and other accessories
- Implementation of Pneumatic circuits
- Implementation of hydraulic circuits
- Test proximity & limit switch.

[VSEC-] Printed Circuit Board (PCB) Design and Production

Teaching Scheme
Theory: 28hrs
Practical: 17hrs

Examination Scheme
Test and hands on practice - 100 Marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to

1. Understand basics of PCB designing.
2. Apply advance techniques, skills and modern tools for designing and fabrication of PCBs.
3. Develop a PCB for any application provided.

Unit 1 **(6 hrs)**

Introduction to PCB designing concepts: Fundamental of electronic components, basic electronic circuits, Need for PCB, Types of PCBs: Single and Multilayer, Technology: Plated Through Hole, Surface Mount. PCB Material, Electronic Component packaging, Basics of printed circuit board designing: Layout planning, general rules and parameters, ground conductor considerations, Design Issues: Transmission line, Cross talk and Thermal management.

Unit 2 **(4 hrs)**

Design rules for PCB: Design rules for Digital circuit PCBs, Analog circuit PCBs, high frequency and fast pulse applications, Power electronic applications, Microwave applications.

Unit 3 **(8 hrs)**

Introduction to Electronic design automation(EDA) tools for PCB designing: Brief Introduction of various simulators, SPICE and PSPICE Environment, Selecting the Components Footprints as per design, Making New Footprints, Assigning Footprint to components, Net listing, PCB Layout Designing, Auto routing and manual routing. Assigning specific text (silkscreen) to design, Creating report of design, creating manufacturing data (GERBER) for design.

Unit 4 **(5 hrs)**

Introduction to PCB Prototyping and Production:PCB Prototyping: CNC Machine, Photo-Lithography process, Screen Printing process and chemical etching. PCB Mass Manufacturing Process: Gerber Generation, CAM, panelization, cleaning, drilling, plating, screen printing, etching, automated optical inspection, tinning, solder resist, legend printing, pcb testing.

Unit 5 **(5 hrs)**

PCB Technology Trends: Multilayer PCBs. Multiwire PCB, Flexible PCBs, Surface mount PCBs, Reflow soldering, Introduction to High-Density Interconnection (HDI) Technology.

PCB Design and Production Laboratory

List of Experiments:

Part A:

Hands on experience experiment on PCB design which includes
Study on types of PCB layers, through Hole and SMD Components.
Schematic Creation and simulation of an electronic circuit
Mapping Components of an electronic circuit
Set Parameters for PCB Design.
Laying Tracks on PCB.
Create PCB Layout of an Electronic Circuit.
Create Device Model and simulation

Part B: Hands on experience experiment on PCB production using SMT Line Setup that consists ofSolder Paste Printer (SPP), Screen Printing Process-Stencil Design, Solder paste Inspection (SPI), Pick and place Machine (PPM), Pick and place Feeders, Heads and Nozzles, P & P Programming concepts, Reflow Oven (RO), Reflow Heating Process, Reflow Solder Defects, Reflow profiling, Automatic Optical Inspection(AOI).

Textbooks:

- R. S. Khandpur, "Printed circuit board design ,fabrication assembly and testing", Tata McGraw Hill 2006.

Reference Books:

- Clyde F. Coombs, Jr, Happy T. Holden,"Printed Circuits Handbook", McGraw-Hill Education, 6th edition, 2016.
- Elaine Rhodes, "Developing Printed Circuit Assemblies: From Specifications to Mass Production", 2008.
- C. Coombs, "Printed Circuits Handbook", McGraw-Hill Professional, 6th edition, 2007.
- D. Brooks, Signal Integrity Issues and Printed Circuit Board Design, Prentice Hall, 2003.
- Open source EDA Tool KiCad Tutorial: http://kicad-pcb.org/help/tutorials/

[VSEC-] Electrical Workshop

Teaching Scheme
Theory: 15hrs
Practical: 30hrs

Examination Scheme
Test and hands on practice - 100 Marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to

1. locate and repair faults in domestic and industrial wiring installations.
2. rewind small transformers.
3. wire up control panels for industrial applications.
4. construct and test small electronic circuits.
5. install an inverter/UPS, and batteries.
6. connect the solar panel to AC and DC loads in a standalone system.

Experiment 1:

Practice with various measuring instruments and tools for testing and maintenance.

- Use of a series test lamp, continuity tester, Megger, multimeter, phase sequence indicator, CRO, lux meter, etc.
- Use of personal protective equipment, hand tools and safety practices.

Experiment 2:

Prepare the test board/extension board and mount accessories like lamp holders, various switches, sockets, MCBs, indicating lamps, etc.

- Identify various electrical accessories and their ratings.
- Select the correct size of board to mount the specified accessories.
- Position the accessories and mount them on board.
- Wire up and test the test board or extension board.

Experiment 3:

Testing and fault detection of domestic and industrial wiring and repair.

- Detect and repair open circuit faults in domestic or industrial wiring.
- Detect and repair short circuit faults in domestic or industrial wiring.
- Detect and repair earth faults in domestic or industrial wiring.

Experiment 4:

Practice wiring a 415 V, 3 HP, 3-phase induction motor as per IE rules.

- Read and interpret the name plate details of the motor.
- Determine the size of the cable.
- Select suitable ICTP/MCB, DOL starter and other accessories.
- Calculate the size and length of conduit.
  Make connections and adjust the overload relay as per the motor rating.
- Start and stop the motor using the starter.

Experiment 5:

Practice winding a small transformer.

- Dismantle the transformer core.
- Measure and determine the size of winding wire for primary and secondary winding.
- Take the dimensions of a bobbin and prepare the bobbin from suitable materials.
- Wind the primary and secondary windings using a winding machine.
- Stack the laminations and fasten them.
- Terminate the winding ends on a terminal board.

Experiment 6:

Control panel wiring for simple control applications like forward, reverse, star-delta starters, and sequential control of motors.

- Study power and control circuit diagrams.
- Mount various control elements like contactors, relays, timers, circuit breakers, sensors, measuring instruments, etc.
- Mount the DIN rail and arrange the wiring by routing, bunching, and tying.
- Test the control panel.

Experiment 7:

Make a printed circuit board for a small electronic circuit.

- Prepare the layout of the PCB and transfer it to the copper-clad board.
- Punch component mounting holes.
- Paint and etch the copper-clad board.
- Drill holes, mount, and solder components.
- Test the circuit.

Experiment 8:

Installation and connection of an inverter or UPS with a battery for domestic wiring.

- Select the rating of the inverter or UPS for a given load and backup.
- Select a suitable place for the installation of an inverter and batteries in the house.
- Install the inverter and batteries and make connections to the load.
- Test the installation under the ON/OFF condition of the supply.

Experiment 9:

Connect the solar panel to the given AC and DC load.

- Select a suitable rating for the solar panel, charge controller, batteries, inverter, MCB, cables, and connectors for the given ac and dc loads.
- Install solar panels on the rooftop with a proper tilt angle.
- Make connections using standard cables and connectors.
- Test the installation for performance.

Experiment 10:

Service and repair of domestic appliances like electric iron, electric kettle, cooking range and geyser.

- Connect and test the given appliance for its functioning.
- Dismantle the appliance.
- Trace and identify (or locate) the faults.
- Replace the faulty parts, assemble the appliance, and test its functioning.

Experiment 11:

Plan and execute an illumination scheme for a given room according to the working situation.

- Design an illumination scheme for a given room and situation.
- Use the open-source software available for the design of illumination schemes.

Experiment 12:

Installation, testing, and maintenance of batteries

- Use of various types of cells.
- Grouping cells for specified voltage and current.
- Practice battery charging.
- Routine, care, maintenance, and testing of batteries.

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School of Electrical and Communication Engineering

Curriculum Structure and Detailed Syllabus

S.Y. B. Tech.
Electrical Engineering

(Effective from: A.Y. 2024-25)

S. Y. B. Tech. Electrical Engineering

[Level 5, UG Diploma] Regular Students Semester -III

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
01	PCC	EE-24001	Signals and Systems	3	1	0	1	3	30	20	50	--	--
02	PCC	EE-24002	Electric Circuit Analysis	2	0	2	1	3	30	20	50	50	50
03	PCC	EE-24003	Analog and Digital Electronics	3	0	2	1	4	30	20	50	50	50
04	OEC	--	Open Elective - I	2	0	0	1	2	30	20	50	--	--
05	HSMC	HS-24003	Indian language	2	0	0	1	2	CIE: 100			--	--
06	VEC	AS-24001	Environmental Studies	1	0	0	2	1	CIE: 100			--	--
07	CEA	AS-24004	Community Engagement Activity (CEA)/Field Project	-	-	-	-	2	--	--	--	CIE: 100	
08	HSMC	HS-24001	Entrepreneurship	2	0	0	1	2	30	20	50	--	--
09	HSMC	HS-24002	Design Thinking and Idea	-	-	2	1	1	--	--	--	CIE: 100	
			Total	**15**	**01**	**06**	**09**	**20**					

[Level 5, UG Diploma] Semester -IV

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
01	PCC	EE 24004	Microcontrollers and Applications	3	0	2	1	4	30	20	50	50	50
02	PCC	EE 24005	Electromagnetic Fields	2	0	0	1	2	30	20	50	--	--
03	PCC	EE 24006	Electrical Machines	3	0	2	1	4	30	20	50	50	50
04	PCC	EE 24007	Numerical Methods and Computer Programming	1	0	2	1	2	CIE:100			50	50
05	VEC-2	AS - 24003	Constitution of India	1	0	0	2	1	CIE: 100			--	--
06	OEC	--	Open Elective – II	2	0	0	1	2	30	20	50	--	--
07	VSEC	--	Electrical Design and Estimation	1	0	2	1	2	30	20	50	--	--
08	MDM	--	Multidisciplinary Minor – I (Clean and Green Energy Technology)	3	0	0	1	3	30	20	50	--	--
			Total	**16**	**00**	**9**	**9**	**20**					

Legends: **L**-Lecture, **T**-Tutorial, **P**-Practical, **S**-Self Study, **Cr**-Credits
ISE-In-Semester-Evaluation, **ESE**-End-Semester-Evaluation, **MSE**-Mid-Semester-Evaluation, **TA**-Teachers' Assessment, **CIE**-Continuous-Internal-Evaluation

Exit option to qualify for UG Diploma:

- Electrical Installation and Costing (3 Credits)
- PLC for Industrial Automation (3 Credits)

S. Y. B. Tech. Electrical Engineering

[Level 5, UG Diploma] Lateral Entry Students- Semester -III

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
01	PCC	EE-24001	Signals and Systems	3	1	0	1	3	30	20	50	--	--
02	PCC	EE-24002	Electric Circuit Analysis	2	0	2	1	3	30	20	50	50	50
03	PCC	EE-24003	Analog and Digital Electronics	3	0	2	1	4	30	20	50	50	50
04	BS-06	--	Matrices, Differential Calculus and Probability	3	0	0	1	3	30	20	50	---	---
05	OEC	*OEC*	Open Elective - I	2	0	0	1	2	30	20	50	--	--
06	HSMC	HS-24003	Indian language	2	0	0	1	2	CIE: 100			--	--
08	HSMC	HS-24001	Entrepreneurship	2	0	0	1	2	30	20	50	--	--
09	HSMC	HS-24002	Design Thinking	-	-	2	1	1	--	--	--	CIE: 100	
			Total	**18**	**01**	**06**	**10**	**21**					

[Level 5, UG Diploma] Lateral Entry Students Semester -IV

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
01	PCC	EE 24004	Microcontrollers and Applications	3	0	2	1	4	30	20	50	50	50
02	PCC	EE 24005	Electromagnetic Fields	2	0	0	1	2	30	20	50	--	--
03	PCC	EE 24006	Electrical Machines	3	0	2	1	4	30	20	50	50	50
04	PCC	EE 24007	Numerical Methods and Computer Programming	1	0	2	1	2	CIE:100			50	50
05	VEC-2	AS - 24003	Constitution of India	1	0	0	2	1	CIE: 100			--	--
06	OE	*<tbd>*	Open Elective - II	2	0	0	1	2	30	20	50	--	--
07	VSEC	*<tbd>*	Electrical Design and Estimation	1	0	2	1	2	30	20	50	--	--
08	MD M	*<tbd>*	Multidisciplinary Minor – I (Clean And Green	3	0	0	1	3	30	20	50	--	--

			Energy)										
09	HSMC	*<tbd>*	Communication Skills	1	0	2	0	2	CIE:100			CIE:100	
Total				**17**	**00**	**19**	**9**	**22**					

Legends: **L**-Lecture, **T**-Tutorial, **P**-Practical, **S**-Self Study, **Cr**-Credits
ISE-In-Semester-Evaluation, **ESE**-End-Semester-Evaluation, **MSE**-Mid-Semester-Evaluation, **TA**-Teachers' Assessment, **CIE**-Continuous-Internal-Evaluation

Open Electives offered by other Departments

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
01	OEC	OEC-24003	Data Analytics	2	0	0	1	2	30	20	50	--	--
02	OEC	OEC-24004	3-D Geometric Modeling	2	0	0	1	2	30	20	50	--	--
03	OEC	OEC-24005	Device Materials	2	0	0	1	2	30	20	50	--	--
04	OEC	OEC-24006	Production Process and Metrology	2	0	0	1	2	30	20	50	--	--
05	OEC	OEC-24007	Linear Algebra	2	0	0	1	2	30	20	50	--	--
06	OEC	OEC-24009	Geo-Informatics	2	0	0	1	2	30	20	50	--	--
07	OEC	OEC-24020	International Standards	2	0	0	1	2	30	20	50	--	--

Multidisciplinary Minor
Title: Electrical Energy Systems

Semester	Course Code	Course Title	L	T	P	S	Cr
IV	MD M-01	Clean and Green Energy	3	0	0	1	3
V	MD M-02	Energy Resources, Economics and Environment	3	0	2	1	4
VI	MD M-03	Energy Audit and Management	3	0	2	1	4
VII	MD M-04	Multidisciplinary Project	0	0	6	1	3
Total			**11**	**0**	**10**	**4**	**14**

Open Electives offered by Electrical Engineering Department

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
01	OE-I	*<tbd>*	Electrical Machines andDrives	2	0	0	1	2	30	20	50	--	--
02	OE-II	*<tbd>*	Principles of Electronic Communication	2	0	0	1	2	30	20	50	--	--
03	OE-III	*<tbd>*	Sensors and Actuators	2	0	0	1	2	30	20	50	--	--
Total				**6**	**0**	**0**	**3**	**6**					

Exit option to qualify for UG Diploma:
Electrical Installation, Estimation and Costing (3 Credits)
PLC for Industrial Automation (3 Credits)

Additional Credits for Exits
After Completion of Second Year

Sr. No.	Course Code	Course Title	L	T	P	Cr	Category
01	VSEC-02	Electrical Design Softwares	1	0	4	3	VSEC
02	VSEC-03	PLC for Industrial Automation	1	0	4	3	VSEC
		Total	**02**	**00**	**08**	**06**	

SEMESTER III

[EE-24001] Signals and Systems

Teaching Scheme
Lectures: 2 Hrs./week
Tutorial: 1 Hr / week
Self Study:1 Hr / week

Examination Scheme
Mid Sem Evaluation - 30 Marks
TA-20 Marks
End Sem Exam- 50 Marks

Course Outcomes:
At the end of the course, students will demonstrate the ability to
1. Classify signals based on their characteristics and perform basic operations on signals.
2. Interpret system characteristics and analyze LTI systems.
3. Analyze the spectral properties of signals using Fourier analysis.
4. Apply Z- transform to study discrete-time signals and systems.

Unit 1 **(5 Hrs)**
Introduction to Signals:
Definition of Signals, Classification of Signals, elementary signals, basic operations on signals

Unit 2 **(6 Hrs)**
System Classification and Properties:
Introduction to Systems, Classification of Systems, Properties of Systems, Impulse response characterization and convolution for CT- LTI and DT-LTI systems, LTI systems characterized by Differential and difference equations.

Unit 3 **(6 Hrs)**
Fourier analysis of Continuous Time Signals:
Fourier analysis for Continuous time signals, Continuous time Fourier Transform, its properties, frequency response..

Unit 4 **(5 Hrs)**
Fourier Analysis of Discrete Time Signals:
Fourier analysis for Continuous time signals, Continuous time Fourier Transform, its properties, frequency response.

Unit 5 **(5 Hrs)**
Z-Transform:
Representation of Signals Using Discrete-Time Complex Exponentials: Z-Transform, Significance and Properties of Region of Convergence, Properties of Z-Transform, Inverse Z-Transform, relationship of z-transform with Fourier transform, applications of Z-transform to solutions of difference equations, Properties of Z transform.

Text Books:
- Simon Haykins and Barry Van Veen, "Signals and Systems", John Wiley and sons
- Michael J. Robert, "Introduction to Signals and Systems", TMH, Second ed., 2003
- Tarun Kumar Rawat "Signals and Systems", Oxford University Press, first edition 2010

Reference Book:

- Alan V Oppenheim, Alan S Willsky, "Signals and systems" PHI, Second ed. 2009
- Shaila Dinkar Apte "Signals and Systems: Principles and Applications", Cambridge University Press.

[EE 24002] Electric Circuit Analysis

Teaching Scheme
Lectures: 2 Hrs./week
Practicals:2 Hrs/week
Self Study:1 Hr / week

Examination Scheme
Mid Sem Evaluation - 30 Marks
TA-20 Marks
End Sem Exam- 50 Marks

Course Outcomes: **(5 Hrs)**

At the end of the course, students will demonstrate the ability to

1. Classify signals based on their characteristics and perform basic operations on signals.
2. Interpret system characteristics and analyze LTI systems.
3. Analyze the spectral properties of signals using Fourier analysis.
4. Apply Z- transform to study discrete-time signals and systems.

Unit 1

Network Topology:

Kirchhoff's laws to network analysis, choice between loop and nodal analysis. Concept of super loop and super mesh, dot convention for coupled circuits. Concept of duality and dual networks. Concept of graph, tree and co-tree, tie set and cut set matrices.

Unit 2 **(5 Hrs)**

Analysis of Transients in the circuit:

Initial and final conditions in network elements. Forced and free response, time constants steady state and transient state response. Classical solution of first and second order differential equations for Series and parallel R-L, R-C, R-L-C circuits.

Unit 3 **(5 Hrs)**

Network Functions for one port and two ports:

Calculations of network functions for ladder and general network. Poles and zeros, restrictions on pole and zero locations for driving point and transfer functions.Time domain behavior from pole and zero plot. Stability of active network.

Two Port Network: Terminal pairs, relationship of two port variables - Z, Y, transmission parameters and hybrid parameters, interconnections of two port networks.

Unit 4 **(5 Hrs)**

Application of the Laplace Transformation:

Review of Laplace transform, inverse Laplace transform. Analysis of electrical circuits with and without initial conditions using Laplace transform for all standard input cases. Shifted and singularity functions, Laplace transform of various periodic and non-periodic waveforms.

Unit 5 **(5 Hrs)**

Sinusoidal steady state analysis of single phase and three phase circuits:

Power transfer and insertion loss of two port network. Effective or RMS values, average power and complex power. Problems in optimizing power transfer in electrical network.

Balanced and unbalanced load in three phase circuits.

Text Books:

- Alexander and Sadiku, "Electric Circuits", 5th edition, 2012. TMH
- M. E. Van Valkenburg, "Network Analysis", Prentice Hall, 3rd edition
- D. Roy Chaudhary, "Network and Systems", New Age International Publications, 2nd edition**.**

Reference Book:

- William H. Hayt, Jack E. Kemmerly, "Engineering Circuit Analysis", McGraw Hill international , 5th edition corrections), Jaico Publishing, 1998**.**

e Learning Resource:

NPTEL Video lectures BY Ankush Sharma IIT Kanpur and by Dr. S. C. Datta Roy IIT Delhi.

[EE 24002] Circuit Simulation Laboratory

Teaching Scheme
Practicals:2 hrs./week

Examination Scheme
In Semester Evaluation: 50 marks
End Semester Evaluation: 50 marks

Course Outcomes:

At the end of this laboratory course the students will demonstrate the ability to:

1. Use MATLAB, Scilab, PSIM, and ATP/EMTP for circuit development and analysis.
2. Compute parameters of a given two port network.
3. Validate the circuit theorems experimentally.

List of Experiments:

1. Transient response in R-L and R-C Network: Simulation/hardware.
2. Transient response of RLC series and parallel circuits: Simulation/hardware.
3. To analyze the responses of RL, RC, and RLC circuit for step, impulse, and ramp input using PSIM software.
4. Determination of Impedance and Admittance parameters of two port network.
5. Fourier analysis of step, ramp, sinusoidal, triangular, saw-tooth, and square waveforms using MATLAB/Scilab and comparison with the computed results.
6. Verification and analysis of maximum power transfer theorem, reciprocity theorem, Tellegen's theorem, and compensation theorem using PSIM software.
7. Determination of Laplace transform and Inverse Laplace transformation using MATLAB.
8. Domain and Cascade connection of second order system using MATLAB.

[EE 24003] Analog and Digital Electronics

Teaching Scheme Lectures: 3 Hrs./week Practical:2Hrs / week
Self-study:1 Hr/week

Examination Scheme
Mid Sem Evaluation - 30 Marks
TA-20 Marks
End Sem Evaluation- 50 Marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to

1. Analyze the characteristics of semiconductor devices and simple circuit.

2. Design and demonstrate the working of op-amp circuits.
3. Develop electronics circuit using Timer IC and voltage regulators.
4. Understand the digital logic families and Construct Combinational logic circuits.
5. Construct Sequential logic circuits.
6. Analyze various ADC/DAC for conversion of signals from analog to digital and vice-versa.

Unit 1 **(5 Hrs)**

Semiconductor Devices and Power Amplifiers:

Introduction to semiconductor devices, BJT, FET, MOSFET. BJT- CB, CE, CC configurations, biasing, FET biasing, MOSFET biasing, NMOS, PMOS, CMOS. Transistor as a switch, DC analysis of CB, CC, CE and FET amplifiers. Low and high frequency response of transistor and FET amplifier.

Unit 2 **(5 Hrs)**

Operational Amplifiers and its Applications:

The ideal Op-Amp, equivalent circuit of Op-Amp, ideal voltage transfer curve, open loop Op-Amp configurations, Op-Amp parameters, block diagram representation of feedback configurations, frequency response, high frequency Op-Amp. Active filters: low pass filter, high pass filter, band-pass filters, band reject filters, all pass filters, comparators and oscillators, DC and AC amplifiers, instrumentation amplifier, logarithmic amplifier, voltage current converter, current to voltage converter, the integrator, the differentiator.

Unit 3 **(5 Hrs)**

Specialized IC Applications:

The 555 Timer as monostable, astable multivibrator, phase locked loops operating principles, 565 PLL applications, voltage regulators- fixed, adjustable, switching, special, analog switch and analog multiplier.

Unit 4 **(5 Hrs)**

Digital Logic Families and Combinational Digital Circuits:

Introduction to digital logic families - TTL, CMOS logic, interfacing CMOS and TTL, Tri-state logic, Introduction to combinational digital circuits, ALU, elementary ALU design, popular MSI chips, digital comparator, parity checker/generator, code converters, priority encoders, decoders/drivers for display devices

Unit 5 **(5 Hrs)**

Sequential Digital Circuits:

Introduction to sequential digital circuits, shift registers, applications of shift registers, serial to parallel converter, parallel to serial converter, ring counter, sequence generator, AsyncHrsonous counters, synchronous counters, counters design using flip flops, special counter IC's, asynchronous sequential counters, applications of counters.

Unit 6 **(5 Hrs)**

A/D and D/A Converters:

Digital to analog converters: weighted resistor/convertor, R-2R Ladder D/A converter, specifications, examples of D/A converter ICs, sample and hold circuit, analog to digital converters: quantization and encoding, parallel comparator A/D converter, successive approximation A/D converter, dual slope A/D converter, A/D converter using voltage to frequency and voltage to time conversion, specifications of A/D converters.

Text Books:

- S. Sedra and K. C. Smith, "Microelectronic Circuits", 7th edition, Oxford Publication, 2017.

- Millman, Halkias and Satyabrata Jit, "Electronic Devices and Circuits", 4th edition, McGraw Hill Education (India) Private Limited, 2015.
- Robert L. Boylestad and Louis Nashelsky, "Electronic devices and circuit theory", 11th edition, Prentice Hall India Ltd, 2015.
- Ramakant A. Gayakwad, "Op-Amps and linear integrated Circuits" 4th edition, Pearson Education, 2015.
- R. P. Jain and Kishor Sarawadekar , "Modern Digital Electronics", 5th edition, Tata McGraw Hill, 2022.
- Anand Kumar, "Fundamentals of Digital Circuits", Prentice-Hall India, 4th edition, 2016.

Reference Books:

- Thomas L. Floyed, "Electronic Devices", 10th edition, Pearson Education, 2018.
- James M. Fiore, "Op Amps and Linear Integrated Circuits-Concepts and Applications", 3rd edition, Cengage Learning, 2018.
- David A. Bell, "Electronic Devices and Circuits", 5th edition, Oxford University Press, 2008.
- Herbert Taub, Donald Schilling, "Digital Integrated Electronics", 1st edition, Tata McGraw Hill, 2017.
- Donald Leech, Albert Malvino, Goutam Saha," Digital Principles and Applications", 8th edition, McGraw Hill Education, 2014.

e Learning Resources:

- Prof. A. N. Chandorkar, IIT Bombay online lecture series on Analog Electronics http://nptel.ac.in/courses/117101106/
- Prof. S. Karmalkar, IIT Madras, online lecture series on Solid State Devices http://nptel.ac.in/courses/117106091/
- Prof. S. C. Datta Roy, IIT Delhi, online lecture series on Analog Electronic Circuits http://nptel.ac.in/courses/108102095/
- Prof. Goutam Saha, IIT Kharagpur, online lecture series on Digital Electronic Circuits https://nptel.ac.in/courses/108/105/108105132/

[EE 24003] Analog and Digital Electronics Laboratory

In Semester Evaluation: 50 marks
End Semester Evaluation: 50 marks

Course Outcomes:

At the end of this course students will demonstrate the ability to,

1. Evaluate the performance characteristics of different semiconductor devices.
2. Build and evaluate the performance of a wide variety of analog circuits using operational amplifier.
3. Use software packages like Proteus, Multisim, PSpice etc.
4. Apply the knowledge for implementation of different circuits using analog ICs.
5. Construct combinational and sequential circuits.
6. Understand the operation of various ADC/DAC.

List of Experiments:

Analog Electronics

The laboratory course can have any 5 experiments from following list. At least 1 experiment should involve simulation using Proteus or appropriate software.

1. To design, assemble and test the wave shaping circuits using diode - clipping and clamping

circuits.

2. To determine the performance characteristics of BJT using DC biasing analysis of CE, CB and CC Configuration.
3. To determine the frequency Response of a BJT/FET single stage and multistage amplifier and to study the effect of coupling and bypass capacitor on the frequency.
4. To obtain the drain and transfer characteristics of JFET.
5. Analysis and applications of active circuits using Op-Amp: (i) Comparator (ii) Zero Crossing Detector, (iii) Integrator, (iv) Logarithmic amplifier, (v) Differentiator.
6. To design, assemble and test the active filters and oscillators using Op-Amp and determine their frequency stability: (i) Low pass, (ii) High pass, (iii) Band pass, (iv) Band reject, (v) All pass, (vi) Phase Shift oscillator, (vi) Wein Bridge Oscillator.
7. To design, assemble and test the Multivibrators using Op-Amp: (i) Schmitt Trigger, (ii) Monostable Multivibrator, (iii) Bistable Multivibrator, (iv) Astable Multivibrator.
8. To operate Timer IC 555/556 as (i) Schmitt Trigger, (ii) Monostable Multivibrator, (iii) Bistable Multivibrator, (iv) Sequence Timer.

Digital Electronics:

The laboratory course can have any 5 experiments from the following list.

1. Verify the truth tables of Logic Gates, Boolean laws and D Morgan's theorem.
2. Realization of combinational circuits (Decoders/Encoders/Code Converters).
3. Realization of Flip Flops using Logic Gates.
4. Design of counters using IC's: Up down, Decade, Synchronous, Binary, BCD counter.
5. Study of D/A and A/D converters (Any one of each class): R-2R ladder, weighted resistor method, successive approximation, voltage to frequency conversion.
6. Design of decoder driver to drive 7 segment LED display.
7. Interfacing of CMOS TTL logic families.
8. To design and test the given electronic application.

(OE-01) Electrical Machines and Drives

Teaching Scheme:
Lectures: 2 Hrs/week
Self Study:1 Hr / week

Examination Scheme:
Mid Semester Evaluation - 30 Marks
TA-20 Marks
End Semester Evaluation- 50 Marks

Course Outcomes:

At the end of this course, the students should be able to,

1. Compare the various power electronic devices on various parameters.
2. Select the appropriate power electronic converter for drives
3. Analyze the parameters, operating characteristics and performance of dc motor drives.
4. Analyze the parameters, operating characteristics and performance of AC drives.
5. Select suitable electrical drive as per industry applications.

Unit 1 **(04 Hrs)**

Power semiconductor Devices:

Basics of power semiconductor devices, Power MOSFET, IGBT, characteristics and triggering circuits, recent developments in devices -Sic, GaN based devices.

Unit 2 **(06Hrs)**

Power Converters:

Power converter topologies as per the application, AC-DC converter, AC-AC Converter, DC-AC Converter, DC-DC Converter, performance of converter with R,RL and RLE loads.Converters for solar supply systems, converters for battery charging

Unit 3 **(05 Hrs)**

DC Motor drives:

Electric drive parts, power and control circuit, DC motor emf and torque production, steady-state and transient characteristics, four quadrant operation, control of torque and speed, single phase and three phase full controlled separately excited dc drive, four quadrant chopper fed dc motor drives.

Unit 4 **(05 Hrs)**

Induction motor Drives:

Induction motor torque-speed and torque-slip characteristics, methods of starting of squirrel cage motors, induction motor drive, speed control, open loop and closed loop V/f control, scalar and vector control, slip power recovery schemes

Unit 5 **(05 Hrs)**

Electrical Drive Selection and Applications:

Electric drive power ratings and capabilities, drive characteristics, load requirements, Selection of motors for different applications.

Text Books:

- G.K.Dubey, Fundamentals of Electrical Drives, Narosa Publishing House, New Delhi , 2001
- Harish C.N.K.De and P. K. Sen, Electric Drives, PHI Learning Pvt. Ltd., New Delhi , 1999)

Reference books:

- S. K. Pillai, A First Course in Electrical Drives, New Age International, New Delhi , 1994
- Vedam Subrahmanyam, Electric Drives: Concepts and Applications, New Age International, New Delhi , 2005

e Learning Resources:

- https://archive.nptel.ac.in/courses/108/104/108104140/

S.Y. B.Tech. (Semester III) – Indian Language: Sanskrit			
Course Code		**Scheme of Evaluation**	**CIE**
Teaching Plan	0-0-0-2	**CIE**	100
Credits	2	**END Semester**	----

Syllabus:

Unit	Contents	L
01.	Introduction to the Sanskrit phonology Sandhi- Guṇa, Vṛddhi, Yaṇ, Savarṇadīrgha Introduction to persons, numbers and the present tense. Introduction to Kāraka and Vibhaktis- 1. Prathamā - Dvitīyā 2. Tṛtīyā – Caturthī	**7**
02.	Introduction to the past tense and the imperative and potential moods Introduction to Kāraka and Vibhaktis- 1. Pañcamī 2. Śaṣṭhī 3. Saptamī Introduction to Samāsa	**7**
03.	Janapadaniveśa - KauṭilīyaArthaśāstra + Rasaratnasamuccaya	**7**
04.	Chapter 1 of the Līlāvatī (up to square roots)	**7**

Course outcomes:

On satisfying the requirements of this course, students will have the knowledge and skills to:

CO1: Familiarize themselves with the basic grammatical categories of Sanskrit.
CO2: Form simple sentences in Sanskrit.
CO3: Understand and extract the meaning of the prescribed Sanskrit scientific texts.
CO4: Co-relate the significance of the scientific literature with the modern knowledge.

Suggested learning resources:

1. V. S. Apte, The student's Sanskrit to English dictionary, 2015. MotilalBanarasidass
2. A. A. Macdonell, A Sanskrit English dictionary, 1893, Oxford press.
3. V. S. Apte, The student's English to Sanskrit dictionary, 2014. MotilalBanarasidass
4. Samskṛt- Śabdadhātu- Rūpāvali, Navneet publications.
5. R. D. Desai, Sanskrit pravesha, 2017, Continental prakashan.
6. Madhav Deshpande, Samskṛtsubodhinī, 2007, University of Michigan.
7. Web Sanskrit Dictionary based on ``The Practical Sanskrit-English Dictionary" by VamanShivaramApte. - http://www.aa.tufs.ac.jp/~tjun/sktdic/
8. Shankar Lal Hari Shankar, RasaRatnaSamucchaya of Vagbhatacharya, 2019, KhemrajShrikrushnadasPrakashan.
9. Colebrook, English translation of the Līlāvatī, (with notes by Banerjee), 1893, Thacker spink&co.
10. Līlāvatī, KhemrajShrikrushnadas, 1908, Shri Venkateshvar steam press Mumbai.
11. R. Shamasastry, Kautilya'sArthashastra, 1915, Bangalore: Government Press.
12. R. Shamasastry, editor: Ashok Kumar Shukla - with Sanskrit Text, Kautilya'sArthashastra, 1915, Bangalore: Government Press.
13. Read Kautilya'sArthashastra for free on: https://www.wisdomlib.org/hinduism/book/kautilya-arthashastrasanskrit/ d/doc905574.html

Indian Language: Pali

Course Code	<tbd>	Scheme of Evaluation	CIE
Teaching Plan	0-0-0-2	CIE	100
Credits	2	END Semester	----

Syllabus:

Unit	Contents	L
01.	Introduction to Pali: What is Pali? Its origin and homeland; Pali Literature: Early Phase, Commentarial Phase and Post commentarial Phase	7
02.	Introduction to Grammar: Alphabets, Pronunciation, Phonetic variation; Noun, Verb and Sentence formation	7
03.	Selected Prose: Nakkhattajātaka, Vīmaṃsakasutta, Kālāmasutta, Vitakkasaṇṭhānasutta	7
04.	Selected Poetry: Selected portion from Dhammapada, Puṇṇikātherī, Kumbhajātaka with pronunciation and recitation	7

Course outcomes:

On satisfying the requirements of this course, students will have the knowledge and skills to:

CO1:become acquainted with some literary specimens of Pali literature in prose and poetry.
CO2:learn ancient Indian moral, humanitarian and scientific values.
CO3:develop interest in Pali language and literature
CO4:learn to appreciate the Indian literary heritage

Suggested learning resources:

1. B. Mahadevan, Bhat Vinayak and NagendraPavan R.N., 'Introduction to IndianKnowledge Systems : Concepts and Applications'
2. Dharmapal 'Indian Science and Technology'
3. Kapil Kapoor, Singh Avdhesh Kumar, 'Indian Knowledge Systems'
4. Chattopadhyaya, Debiprasad, History of science and technology in ancient India: the beginnings, Firma KLM Pvt. Ltd. 1986.
5. Irfan Habib (ed.), People's History of India – Vol 20 : Technology in Medieval India, c. 650–1750, Aligarh Historians Society and Tulika Books, 2016.
6. Jan Gonda, A History of Indian Literature, Otto Harrassowitz, Wiesbaden, 1975.
7. L. Gopal and V. C. Shrivastava, History of Agriculture in India (Upto 1200 A. D.), Concept Publishing, New Delhi, 2008.
8. PushkarSohoni, Introduction to the History of Architecture in India, IISER, Pune, 2020.
9. SurendranathDasgupta, A History of Indian Philosophy, Cambridge University press, 1922.
10. RadhavallabhTripathi, Vāda in theory and practice : studies in debates, dialogues and discussions in Indian intellectual discourses, IIAS, Shimla, 2016.
11. ThanuPadmanabhan (ed.), Astronomy in India : A Historical Perspective, Indian National Science Academy, Springer, New Delhi. 2014.

(VEC)- Environmental Studies			
Course Code	<tbd>	**Scheme of Evaluation**	**CIE**
Teaching Plan	1--0-0-1	**CIE**	100
Credits	1	**END Semester**	----

Syllabus:

Unit	Contents	L
01.	**Humans and the Environment:** The man-environment interaction: Humans as hunter-gatherers; Mastery of fire; Origin of agriculture; Emergence of city-states; Great ancient civilizations and the environment; Middle Ages and Renaissance; Industrial revolution and its impact on the environment; Population growth and natural resource exploitation; Global environmental change. The emergence of environmentalism: Anthropocentric and eco-centric perspectives (Major thinkers); The Club of Rome- Limits to Growth; UN Conference on Human Environment 1972; World Commission on Environment and Development and the concept of sustainable development; Rio Summit and subsequent international efforts.	**1**
02.	**Natural Resources and Sustainable Development** Overview of natural resources: Definition of resource; Classification of natural resources- biotic and abiotic, renewable and non-renewable. Biotic resources: Major type of biotic resources- forests, grasslands, wetlands, wildlife and aquatic (fresh water and marine); Microbes as a resource; Status and challenges. Water resources: Types of water resources- fresh water and marine resources; Availability and use of water resources; Environmental impact of over-exploitation, issues and challenges; Water scarcity and stress; Conflicts over water. Soil and mineral resources: Important minerals; Mineral exploitation; Environmental problems due to extraction of minerals and use; Soil as a resource and its degradation. Energy resources: Sources of energy and their classification, renewable and non-renewable sources of energy; Conventional energy sources- coal, oil, natural gas, nuclear energy; Non-conventional energy sources- solar, wind, tidal, hydro, wave, ocean thermal, geothermal, biomass, hydrogen and fuel cells; Implications of energy use on the environment. Introduction to sustainable development: Sustainable Development Goals (SDGs)- targets and indicators, challenges and strategies for SDGs.	**2**
03.	**Environmental Issues: Local, Regional and Global** Environmental issues and scales: Concepts of micro-, meso-, synoptic and planetary scales; Temporal and spatial extents of local, regional, and global phenomena. Pollution: Impact of sectoral processes on Environment, Types of Pollution- air, noise, water, soil, municipal solid waste, hazardous waste; Transboundary air pollution; Acid rain; Smog. Land use and Land cover change: land degradation, deforestation, desertification, urbanization. Biodiversity loss: past and current trends, impact. Global change: Ozone layer depletion; Climate change.	**2**
04.	**Conservation of Biodiversity and Ecosystems:** Biodiversity and its distribution: Biodiversity as a natural resource; Levels and types of biodiversity; Biodiversity in India and the world; Biodiversity hotspots; Species and ecosystem threat categories. Ecosystems and ecosystem services: Major ecosystem types in India and their basic	**2**

characteristics forests, wetlands, grasslands, agriculture, coastal and marine; Ecosystem services- classification and their significance. Threats to biodiversity and ecosystems: Land use and land cover change; Commercial exploitation of species; Invasive species; Fire, disasters and climate change.

05. Environmental Pollution and Health **2**

Understanding pollution: Production processes and generation of wastes; Assimilative capacity of the environment; Definition of pollution; Point sources and non-point sources of pollution. Air pollution: Sources of air pollution; Primary and secondary pollutants; Criteria pollutants- carbon monoxide, lead, nitrogen oxides, ground-level ozone, particulate matter and sulphur dioxide; Other important air pollutants- Volatile Organic compounds (VOCs), Peroxyacetyl Nitrate (PAN), Polycyclic aromatic hydrocarbons (PAHs) and Persistent organic pollutants (POPs); Indoor air pollution; Adverse health impacts of air pollutants; National Ambient Air Quality Standards. Water pollution: Sources of waterpollution; River, lake and marine pollution, groundwater pollution; water quality Water quality parameters and standards; adverse health impacts of water pollution on human and aquatic life. Soil pollution and solid waste: Soil pollutants and their sources; Solid and hazardous waste; Impact on human health. Noise pollution: Definition of noise; Unit of measurement of noise pollution; Sources of noise pollution; Noise standards; adverse impacts of noise on human health. Thermal and radioactive pollution: Sources and impact on human health and ecosystems.

06. Climate Change: Impacts, Adaptation and Mitigation **2**

Understanding climate change: Natural variations in climate; Structure of atmosphere; Anthropogenic climate change from greenhouse gas emissions– past, present and future; Projections of global climate change with special reference to temperature, rainfall, climate variability and extreme events; Importance of 1.5 °C and 2.0 °C limits to global warming; Climate change projections for the Indian sub-continent. Impacts, vulnerability and adaptation to climate change: Observed impacts of climate change on ocean and land systems; Sea level rise, changes in marine and coastal ecosystems; Impacts on forests and natural ecosystems; Impacts on animal species, agriculture, health, urban infrastructure; the concept of vulnerability and its assessment; Adaptation vs. resilience; Climate-resilient development; Indigenous knowledge for adaptation to climate change. Mitigation of climate change: Synergies between adaptation and mitigation measures; Green House Gas (GHG) reduction vs. sink enhancement; Concept of carbon intensity, energy intensity and carbon neutrality; National and international policy instruments for mitigation, decarbonizing pathways and net zero targets for the future; Energy efficiency measures; Renewable energy sources; Carbon capture and storage, National climate action plan and Intended Nationally Determined Contributions (INDCs); Climate justice.

07. Environmental Management **2**

Introduction to environmental laws and regulation: Constitutional provisions- Article 48A, Article 51A (g) and other derived environmental rights; Introduction to environmental legislations on the forest, wildlife and pollution control.

Environmental management system: ISO 14001, Life cycle analysis; Cost-benefit analysis, Environmental audit and impact assessment; Environmental risk assessment, Pollution control and management; Waste Management- Concept of 3R (Reduce, Recycle and Reuse) and sustainability; Ecolabeling /Ecomark scheme

08. Environmental Treaties and Legislation **2**

Major International organizations and initiatives: United Nations Environment Programme (UNEP), International Union for Conservation of Nature (IUCN),World Commission on Environment and Development (WCED), United Nations Educational, Scientific and Cultural Organization (UNESCO), Intergovernmental Panel on Climate Change (IPCC), and Man and the Biosphere (MAB) programme.

Case Studies and Field Work **1**

09. Discussion on one national and one international case study related to the environment and sustainable development.

Field visits to identify local/regional environmental issues, make observations including data collection and prepare a brief report.

Documentation of campus biodiversity, Campus environmental management activities such as solid waste disposal, water management and sewage treatment

**** This syllabus is as prescribed by the UGC and modified as per NEP Structure**

Course outcomes:

Students will be able to

CO1: Aware about different sustainable techniques for conservation and management of natural resources and importance of studying sustainable development goals

CO2: Aware about sources of different kinds of pollution and its types, sensitize themselves to adverse health impacts of pollution and knowing the techniques of pollution prevention and management

CO3: Aware about factors impacting biodiversity loss and ecosystem degradation in India and the world & major conservation strategies taken in India, importance of biodiversity and their role in conserving biodiversity

CO4: Aware about Climate change with reference to impacts, adaptation & mitigation strategies

CO5: Learn about Environmental management system, Environmental legislation, policies, international treaties etc and our country's stand on and responses to the major international agreements. Major international institutions and programmes and the role played by them in the protection and preservation of the environment.

Suggested learning resources:

1. Hughes, J. Donald (2009) An Environmental History of the World- Humankind's Changing Role in the Community of Life, 2nd Edition. Routledge.
2. Gilbert M. Masters and W. P. (2008). An Introduction to Environmental Engineering and Science, Ela Publisher (Pearson)
3. Rajagopalan, R. (2011). Environmental Studies: From Crisis to Cure. India: Oxford University Press.
4. Krishnamurthy, K.V. (2003) Textbook of Biodiversity, Science Publishers, Plymouth, UK
5. Jackson, A. R., & Jackson, J. M. (2000). Environmental Science: The Natural Environment and Human Impact. Pearson Education.
6. Pittock, Barrie (2009) Climate Change: The Science, Impacts and Solutions. 2nd Edition. Routledge.

(HSMC) Principles of Entrepreneurship

Teaching Scheme
Lectures: 2 Hrs./week
Self Study:1 Hr / week

Examination Scheme
Mid Sem Evaluation - 30 Marks
TA-20 Marks
End Sem Exam- 50 Marks

Syllabus:

Unit	Contents	L
01.	Entrepreneurship: Meaning of entrepreneurship – Types of Entrepreneurships – Traits of entrepreneurship – Factors promoting entrepreneurship- Barriers to entrepreneurship- the entrepreneurial culture- Stages in entrepreneurial process – Women entrepreneurship and economic development- SHG.	**6**
02.	Developing Successful Business Ideas: Recognizing opportunities – trend analysis – generating ideas – Brainstorming, Focus Groups, Surveys, Customer advisory boards, Day in the life research – Encouraging focal point for ideas and creativity at a firm level-Protectingideas from being lost or stolen – Patents and IPR.	**6**
03.	Opportunity Identification and Evaluation Opportunity identification and product/service selection – Generation and screening the project ideas – Market analysis, technical analysis, Cost benefit analysis and network analysis- Project formulation – Assessment of project feasibility- Dealing with basic and initial problems of setting up of Enterprises.	**6**
04.	Business Planning Process Meaning of business plan- Business plan process- Advantages of business planning preparing a model project report for starting a new venture (Team-based project work)	**5**
05.	Funding Sources of Finance- Venture capital- Venture capital process- Business angles Commercial banks- Government Grants and Schemes.	**5**

Course Outcomes:

Students will be able to

CO1:enable the students to understand the concept of Entrepreneurship and to learn the professional behaviour expected of an entrepreneur.

CO2:identify significant changes and trends which create business opportunities and to analyse the environment for potential business opportunities.

CO3:provide conceptual exposure on converting idea to a successful entrepreneurial firm

Suggested learning resources:

1. Reddy, Entrepreneurship: Text & Cases - Cengage, New Delhi.
2. Kuratko/rao, Entrepreneurship: a south asianperpective.- Cengage, New Delhi.
3. Leach/Melicher, Entrepreneurial Finance – Cengage. , New Delhi.
4. K.Sundar – Entrepreneurship Development – Vijay Nicole Imprints private Limited
5. Khanka S.S., Entrepreneurial Development, S.Chand& Co. Ltd., New Delhi, 2001.
6. Sangeeta Sharma, Entrepreneurship Development, PHI Learning Pvt. Ltd., 2016.

7. P. Khanna, "Industrial Engineering and Management", Dhanpatrai publications Ltd, New Delhi.
8. Barringer, B., Entrepreneurship: Successfully Launching New Ventures, 3rd Edition, Pearson, 2011.
9. Bessant, J., and Tidd, J., Innovation and Entrepreneurship, 2nd Edition, John Wiley &Sons, 2011.
10. Desai, V., Small Scale Industries and Entrepreneurship, Himalaya Publishing House, 2011.
11. Donald, F.K., Entrepreneurship- Theory, Process and Practice, 9th Edition, Cengage Learning, 2014.

(HSMC) Design Thinking and Idea Lab (DTIL)			
Course Code	<tbd>	**Scheme of Evaluation**	**CE & ESE**
Teaching Plan (L-T-P-S)	0-0-2-1	**MID Semester**	Individual Assignments/Group tasks- 40 marks Class/team participation- 10 marks
Credits	1	**END Semester**	Project Based Learning (PBL)- 50 marks (50 – PBL & 10 participation

Syllabus:

Unit	**Contents**	**Practical**
	Part 1- THINKING (Methodology of Design Thinking)	
01.	**An Insight to Learning** Experiential Learning Styles, Self-assessment Psychological Principles in Design Thinking Perception & Observation, Imagination & Creative Confidence (lateral thinking & 6 thinking hats)	**4**
02.	**Design Thinking Framework** Introduction to different frameworks of DT, Stanford d. school framework Empathize, Define, Ideate, Prototype, Test Case Study: IDEO Shopping Cart, etc.	**2**
03.	**User-Design Relationship** Levels of Designs Understanding users through interviews, personas, empathy maps/affinity diagrams/journey maps and need identification	**4**
04.	**Introduction to Human Centric Tools in Design Thinking Process** Brainstorming & Mind mapping POV and HMW	**2**
	Part 2- DESIGN (Idea Lab) Applications of the Principles- Department Level	
05.	**Process of Product Design**	**2**

Process of simple Product Design using real life problem statements from our daily routine activities, Design Thinking Approach, Stages of Product Design, Examples of best product designs and functions. Hands on Lab Assignment – Simple routinely used Product Design. Hands on demonstration of how to translate the ideas into physical objects. Better visualization of the ideas and concepts using, IDEA LAB/FAB LAB facilities such as Wood router, Laser cutting of thin plastic sheets, clay modelling, Expandable Polystyrene etc

06. Prototyping **4**

What is Prototype? Understanding necessity of making prototypes by building the prototypes for pre-selected Engineering problem, using one or combinations of the digital fabrication techniques & electronics fabrication systems.

07. Testing **2**

Testing, Sample Example, Test Group Marketing Feedback, Re-Design & Re-Create

08. Feedback, Re-Design & Re-Create **2**

Final Presentation – "Solving Practical Engineering Problem through Innovative Product Design & Creative Solution"

Course outcomes:

Students will be able to

CO1: Outline various learning styles and psychological principles and Infer Design Thinking principles & methodology.

CO2: Explain the levels of designs and Experiment with the process using human centric tools.

CO3: Propose real-time innovative engineering product designs and Choose appropriate frameworks, strategies, techniques for prototype development.

CO4: Appraise user feedback and Propose corrective innovative solutions to meet project requirements using critical thinking skills.

Suggested Learning Resources:

1. Norman, D. (2013). The Design of Everyday Things. Basic Books, NY.
2. Norman, D. (2004). Emotional Design. Basic Books, NY.
3. Brown, T. (2019). Change by Design. HarperCollins Publishers, NY.
4. Lal, D. M. (2021). Design Thinking- Beyond the Sticky Notes. Sage Publications India Pvt. Ltd.
5. Malik, A. D. M. (2019). Design Thinking for Educators. Notion Press, Chennai, India.
6. E. F. Crawley, "Creating the CDIO Syllabus, a universal template for engineering education," *32nd Annual Frontiers in Education*, Boston, MA, USA, 2002, pp. F3F-F3F, doi: 10.1109/FIE.2002.1158202.
7. Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., &Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. *Journal of engineering education*, *94*(1), 103-120.
8. Panke, S. (2019). Design thinking in education: Perspectives, opportunities and challenges. *Open Education Studies*, *1*(1), 281-306.
9. Parmar, A. J. (2014, October). Bridging gaps in engineering education: Design thinking a critical factor for project based learning. In *2014 IEEE frontiers in education conference (FIE) proceedings* (pp. 1-8). IEEE.

10. Thompson, L., &Schonthal, D. (2020). The Social Psychology of Design Thinking. California Management Review, 62(2), 84–99. https://doi.org/10.1177/0008125619897636

Direct S.Y. B.Tech. Semester III (All branches)

Matrices, Differential Calculus and Probability (MDCP)

Teaching Scheme	**Examination Scheme**
Lectures: 3 Hrs./week	Mid Sem Evaluation - 30 Marks
Self Study:1 Hr / week	TA-20 Marks
	End Sem Exam- 50 Marks

Course Objectives: Necessity for the foundation of Engineering and Technology being Mathematics, the main aim is to teach mathematical methodologies and models, develop mathematical skills and enhance thinking power of students.

Syllabus:

Unit	**Contents**	**L+T+S**
01.	**Matrix Algebra:** Properties of Matrices and Determinants, Solutions of Systems of linear equations using Gauss Elimination method, Eigen Values and Eigen Vectors. **S:** Properties of Matrices and Determinants	**6+0+3**
02.	**Vector Differential Calculus:** Functions of several variables (Domain and Range), PartialDerivatives,TheChainRule, Vector differentiation, gradient, divergence, and curl. **S:** Review of Vector Algebra	**6+0+3**
03.	**Ordinary Differential Equations:** First order Ordinary Differential Equations - Variable Separable, Homogeneous, Linear; Higher order linear equations with constant coefficients, non-homogeneous higher order linear differential equations with constant coefficients: method of variation of parameters; Applications to Initial value problems: Simple Electrical Circuits. Definition of Laplace Transform, Laplace Transform of standard functions, basic properties to solve ODE: linearity and LT of derivatives. **S:** First order Ordinary Differential Equations - Variable Separable, Homogeneous ODEs	**12+0+6**
04.	**PartialDifferential Equations:** Fourier Series; Partial differential equations. Initial and Boundary value problems by separation of variables method, boundary value problems: Vibration of string: one dimensional wave equation. **S:** Types of PDEs	**8+0+4**
05.	**Probability:** Mean, median, mode, standard deviation, combinatorial probability, compound, and conditional probability. Probability distributions, Binomial distribution, Poisson distribution, Normal distribution. **S:** Compound and conditional probability.	**8+0+4**

Outcomes: Students will be able to

- **Define** matrices, linear equations, and determinants, **recall** basics of probability theory,probability distribution, gradient, divergence and curl, Laplace Transform, ODE and PDE.
- **Identify** types of ordinary differential equations and partial differential equations, **state** the formulae for Fourier coefficients, basic concepts of probability, probability distributions, Laplace Transform.
- **Solve** ODEs and PDEs, **find** Fourier series expansions, **analyze,** and **calculate** eigen values, eigen vectors, **evaluate** probability of compound events, **find** probabilities using standard distributions, **solve** ODE using Laplace Transform.
- **Prove**theorems, **solve** theoretical problems.
- **Apply** concepts of ODE and PDE, Matrix algebra, Calculus and Probability to various problems including real life problems.

Note 1:

- To measure CO1, questions may be of the type- define, identify, state, match, list, name etc.
- To measure CO2, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.
- To measure CO3, questions will be based on applications of core concepts.
- To measure CO4, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, prove implications or corollaries of theorems, etc.
- To measure CO5, some questions may be based on self-study topics and also comprehension of unseen passages.

Textbook:

- Advanced Engineering Mathematics (10^{th} edition) by Erwin Kreyszig, Wiley Eastern Ltd.
- Thomas's Calculus (12th edition) by Maurice D. Weir, Joel Hass, Frank R. Giordano, Pearson Education.

Reference Books:

Calculus for Scientists and Engineers by K.D Joshi, CRC Press.

- A course in Calculus and Real Analysis (1^{st} edition) by Sudhir Ghorpade and Balmohan Limaye, Springer-Verlag, New York.
- Applied Mathematics Vol.1 (Reprint July 2014) by P.N. Wartikar and J.N. Wartikar, Pune Vidhyarthi Griha Prakashan Pune.
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SEMESTER IV

[EE 24004] Microcontrollers and Applications

Teaching Scheme
Lectures:3 Hrs./week
Practical: 2 Hrs / week
Self Study:1 Hr / week

Examination Scheme
Mid Sem Evaluation - 30 Marks
TA-20 Marks
End Sem Evaluation- 50 Marks

Course Outcomes:

At the end of the course, students will be the able to

1. Differentiate amongst various architectures of microcontrollers
2. Impart microcontroller programming and design skills.
3. Undertake problem identification formulation and selection of appropriate microcontroller as per the applications
4. Interface and use different peripherals with microcontrollers
5. Compare and analyze different microcontrollers for the real world applications
6. Evaluate and compare the performance of microcontrollers

Unit 1 **(8 Hrs)**

Introduction to Microcontroller:

Numbering system, Microcontrollers Vs Microprocessors, RISC and CISC architecture comparison. Von-Neumann vs. Harvard architecture, comparison between 8-bit, 16-bit, 32-bit microcontroller. Stack and use of stack pointer. Memory structure, Data Memory, Program Memory and execution of programs.

Unit 2 **(8 Hrs)**

Programming with microcontroller:

Programming: Concept of assembler directives, editor, linker, loader, debugger, simulator, emulator. Instruction set, basic programming using assembly instructions. Introduction to embedded-C, Integrated Development Environment (IDE), cross compiler, ISP, software delay generation.

Unit 3 **(8 Hrs)**

8 Bit micro-controller:

Introduction to 8 bit microcontroller, Addressing Modes & Instruction Set, architecture and PIN description, Interrupts and Operating Modes, Analog Input-Output and PWM, Digital Input-Output, Memory Mapping (internal as well as external) of microcontroller.

Unit 4 **(6 Hrs)**

I/O Interfacing:

I/O programming, interfacing with simple switch, LED, Keypad programming. Timers, various modes of operations of timers, counters, PWM programming.

Unit 5 **(6 Hrs)**

Communication Protocols:

Serial peripheral interface (SPI), SPI based memory interfacing, Universal Serial Communications Interface (USCI) interfacing and programming, Interrupt understanding and interfacing, I2C based RTC interfacing , WDT (Watch dog timer).

Unit 6

External Peripheral Interfacing: **(6 Hrs)**

Analog to digital convertor, interfacing with external serial and parallel ADC's, Digital to analog convertor (DAC), Interfacing with DAC, Interfacing with stepper motor and DC motor, Comparative analysis of different 8 bit microcontrollers.

List of Recommended Books:

Text Books:

- Mazidi, "8051 microcontroller & embedded system" 3rdEdition ,Pearson
- Mazidi, "PIC microcontroller & embedded system" 3rdEdition ,Pearson
- Kenneth J. Ayala, "8051 Microcontroller: Programming, Architecture and Interfacing", Thomas Delmar Learning, Third ed., 2007.
- Newnes, 1st Edition, 2010 "MSP430 Microcontroller Basics" by John H Davies

Reference Books:

- Kenneth J. Ayala, "The 8051 Micro-controller – Architecture, Programming & Applications", Penram International & Thomson Asia, Second Edition.
- John B. Peatman, "Design with PIC Micro-controllers", Pearson Education Asia, Low Price Edition
- MSP430 Technical Reference Manual
- Newnes Publication, 2009 *Texas Instruments MSP 430 microcontroller, Guide and Datasheet
- Muhammad A. Mazidi, "AVR Microcontroller and Embedded Systems: Assembly and C", Pearson; 1st edition, 2015

[EE 24003] Microcontrollers and Applications: Laboratory

CIE 100 marks **In Semester Evaluation: 50 marks**
End Semester Evaluation: 50 marks

Course Outcomes:

At the end of the course, students will be the able to

1. Understand and apply the fundamentals of assembly/embedded 'c' level programming of microprocessors and microcontroller
2. Analyze problems and apply a combination of hardware and software to address the problem.

List of Experiments

1. GPIO toggling.
2. Seven segment LED interfacing with microcontroller
3. Keypad interfacing with microcontroller.
4. ADC interfacing with microcontroller with the help of waveform generation.
5. Timers and counters.
6. UART interfacing.
7. Interrupts in microcontrollers.
8. PWM generation using a microcontroller.
9. DC/stepper motor interfacing with a microcontroller.
10. I2C and SPI based peripheral interfacing.

(EE 24005) Electromagnetic Fields

Teaching Scheme
Lectures:2 Hrs./week
Self Study :1 Hr/week

Examination Scheme
Mid Sem Evaluation - 30 Marks
TA-20 Marks
End Sem Evaluation - 50 Marks

Course Outcomes:
At the end of the course, students will demonstrate the ability to

1. Intuitively visualize and explain ideas related to Static and dynamic electromagnetic (EM) fields, energy, and power.
2. Analyse and calculate the capacitance, force and energy in Electrostatic devices.
3. Solve and analyse the problems related to magnetic field.
4. Compute and analyze performance and behavior of (economically important applications) electromechanical devices such as motors, generators and transformers.
5. Apply Maxwell's field equations to analyze and improve the performance of electromechanical devices and to develop space-related thinking ability.
6. Analyze and apply the process of energy conversion and energy transfer of electromechanical devices

Unit 1 **(6 Hrs)**

Vector Analysis:

(A) Vector Algebra & Coordinate system- Review (scalars & vectors) , Vector algebra (vector addition and subtraction), Position and distance vectors, Vector Multiplication -The Dot product and cross product, Triple Product, components of vector, Transformation of vectors, The coordinate systems (Cartesian, cylindrical and spherical).

(B) Vector Calculus: Introduction, differential length, area and volume, line, surface and volume integrals, Del operator, gradient of a scalar, divergence of a vector and divergence theorem, curl of a vector and Stokes's theorem, Laplacian of a scalar, classification of vector fields.

Unit 2 **(6 Hrs)**

Electrostatic Fields :

Introduction, Coulomb's law and field intensity, electric field due to continuous charge distributions, a line charge, surface charge, volume charge, Streamlines and Sketches of Fields.

Electric Flux Density, Gauss's Law and Divergence, applications of Gauss's law, point charge, infinite line charge, infinite surface charge, uniformly charged sphere. Energy and Potential: Energy Expended in Moving a Point Charge in an Electric Field, The Line Integral, Definition of Potential Difference and Potential, The Potential Field of a Point Charge, The Potential Field of a System of Charges: Conservative Property, Potential Gradient, Relationship between E and V - Maxwell's Equation .The Electric Dipole and flux lines, Energy Density in the Electrostatic Field

Unit 3 **(6 Hrs)**

Electric Field in Material Space and Electrostatic Boundary Value Problem:

Introduction, properties of materials, convection and conduction currents, conductors, polarization in dielectrics, dielectric constant and strength, Poisson's and Laplace's equations, uniqueness theorem, general procedures for solving Poisson's and Laplace's equation, resistance and capacitance, parallel plate, coaxial and spherical capacitors, Capacitance of a Two-Wire Line, Using Field Sketches to

Estimate Capacitance in Two-Dimensional Problems.

Unit 4 **(6 Hrs)**

Magnetostatic fields:

The Steady Magnetic Field: Bio-Savart Law, Ampere's Circuital Law-Maxwell's equation, Curl, Stokes' Theorem, Magnetic Flux and Magnetic Flux Density, The Scalar and Vector Magnetic Potentials, Derivation of the Steady-Magnetic-Field Laws. Magnetic Forces: Force on a Moving Charge, Force on a Differential Current Element, Hall Effect, Force between Differential Current Elements, Force and Torque on a Closed Circuit, forces due to magnetic fields, magnetic torque and moment and magnetic dipole. Materials and Inductance: The Nature of Magnetic Materials, Magnetization and Permeability, Magnetic Boundary Conditions, The Magnetic Circuit, Potential Energy and Forces on Magnetic Materials, inductors and inductances, Self and Mutual inductance of simple configurations, magnetic energy, magnetic coupled circuits, force on magnetic materials

Unit 5 **(6 Hrs)**

Time Varying Fields and Maxwell's Equations:

Faraday's law-Maxwell's Equation, Displacement current and current density, Maxwell's equation in point form and integral form. Time varying potentials, time harmonic fields Boundary condition for time varying field, transformer and motional, electromotive forces, stationary loop in time varying B field (transformer emf), moving loop in static B field (motional emf), Magnetic Brake, Magnetic Levitation, electromagnetic launcher.

Unit 6 **(4 Hrs)**

Transmission Lines & Numerical techniques:

Transmission Lines: distributed parameter circuits, traveling and standing waves, impedance matching, Smith chart, analogy with plane waves. Transients and pulse propagation on transmission line. Numerical Techniques: Advantages of numerical techniques Separation of variable method, Method of images, Finite difference method (FDM), Finite Element method (FEM), Application of numerical techniques.

Text Books:

- Matthew N. O. Sadiku, "Elements of Electromagnetics", Oxford University publication, 6th edition, 2014.
- A.Pramanik, "Electromagnetism - Theory and applications", PHI Learning Pvt. Ltd, New Delhi, 2nd edition, 2009.
- A.Pramanik, "Electromagnetism – Problems with solution", Prentice Hall of India, Pvt. Ltd., 2nd edition, 2012.

Reference Books:

- G. W. Carter, "The electromagnetic field in its engineering aspects", Longmans, 1st edition, 1954.
- W. J. Duffin, "Electricity and Magnetism",McGraw Hill Publication, 3rd edition(Rev),1980.
- W. J. Duffin, "Advanced Electricity and Magnetism", McGraw Inc. US,1968.
- E. G. Cullwick, "The Fundamentals of Electromagnetism", Cambridge University Press, 3rd edition, 1966.
- B. D. Popovic, "Introductory Engineering Electromagnetics", Addison-Wesley, Educational Publishers Inc, International Edition, 1971.
- William Hayt, "Engineering Electromagnetics", Tata McGraw Hill Education Pvt. Ltd., 7th edition, 2012.

e - Learning resource:

• nptel course on Electromagnetic Fields by Prof. Harishankar Ramachandran Department of Electrical Engineering IIT Madras

https://archive.nptel.ac.in/courses/108/106/108106073

[EE 24006] Electrical Machines

Teaching Scheme
Lectures:3 Hrs./week
Practical:2 Hrs/week
Self Study :1 Hr/week

Examination Scheme
Mid Semester Evaluation - 30 Marks
TA – 20 Marks
End Semester Evaluation - 50 Marks

Course Outcomes:
At the end of this course, the students should be able to,

1. Explain the principles of operation of transformer, dc machine and three phase and single phase induction motors.
2. Select a suitable transformer, dc machine, induction machine as per various industrial applications.
3. Evaluate and analyze the steady state parameters, operating characteristics and performance of transformers of dc machine and induction machine
4. Test the performance of transformers and ac / dc and machines

Unit 1 **(8 Hrs)**

Single Phase and Three Phase Transformer:
Review of transformer, phasor diagrams, efficiency, voltage regulation, parallel operation, per unit impedance, excitation, switching transients, auto transformers, three phase transformer construction, standard connections, vector groups, open delta and Scott Connection, Phase conversion, three winding transformers, on load tap changing of transformers, modern trends in transformers, type and routine tests, testing standards.

Unit 2 **(8 Hrs)**

Electromechanical Energy Conversion Principles:
Energy in a magnetic systems, field energy and mechanical force, energy in singly and multiply excited magnetic systems, determination of magnetic force and torque from energy and co-energy, Forces and torques in magnetic field systems, dynamic equations of electromechanical systems and analytical technique

Unit 3 **(8 Hrs)**

DC Machines :
Review, generator operation, armature and field systems, types, emf equation, armature windings, characteristics and applications, armature reaction – demagnetizing and cross magnetizing mmfs, commutation process, bad commutation and remedies.
DC motor operation, significance of back emf, torque equation, types, characteristics and selection criterions, starting, speed control, losses and efficiency, condition for maximum efficiency, braking, applications, type and routine tests

Unit 4 **(8 Hrs)**

Three Phase Induction Machine (Asynchronous Machines):
Introduction, construction , types, flux and MMF waveforms, equivalent circuit, no load and on load operation, phasor diagram, power factor, power output, OC and SC test, torque developed, starting methods, deep cage bars, speed control, cogging and crawling, circle diagram, maximum torque and power estimation, efficiency, breaking, testing and applications, Induction generator operation, testing

IS, energy efficient motors

Unit 5 **(8 Hrs)**

Fractional Kilowatt Machines:

Fractional kilowatt motors, basics of single phase motors, construction, types, double revolving field theory, circuit model, phasor diagram, determination of parameters, losses and efficiency, applications, two phase induction motor

Text Books:

- D. P. Kothari and I. J. Nagrath, "Electric Machines", Tata Mc Graw Hill Publication, 4th edition 2010, Reprint 2012.
- E. Fitzgerald, C. Kingsley, S. D. Umans, "Electrical Machinery", Tata Mc Graw Hill, 6th edition, 2002.
- P. S. Bimbhra: Electrical Machinery – Khanna Publishers, 7th edition, 2011
- B. L Thareja, A. K. Thareja,, " A text book of Electrical Technology, Vol. II, AC and DC Machines" S. Chand Publication, Multicolour edition, Reprint 2004

Reference Books:

- Nasser Syed, "Electrical Machines and Transformers", A New York, MacMillan 1984.
- Langsdorf A. S., "Principles of DC Machines", 6th Edition, McGraw Hill Book Company 1959.
- P. C. Sen., "Principles of Electric Machines and Power Electronics", 2nd edition, John Wiley and Sons Inc., 1997.
- M. G. Say, "Alternating Current Machines", 5th edition, Low price edition, ELBS, Reprinted 1994
- Bhag S. Guru and Huseyin R. Hiziroglu, "Electric Machinery and Transformers", 3rd Indian edition, Oxford University Press, Reprint 2014.

e Learning resource:

- https://nptel.ac.in/courses/108105017; NPTEL: Electrical Engineering, Electrical Machines –I and Electrical Machines -II.

[EE 24006] Electrical Machines Laboratory

Examination Scheme
In Semester Evaluation: 50 marks
End Semester Evaluation: 50 marks

Course Outcomes:

At the end of laboratory course the students will be able to,

1. Select a suitable motor as per the application.
2. Determine transformer, dc machine and induction machine parameters by testing.
3. Estimate practically losses in transformers, dc machine and induction motors.
4. Obtain practically efficiency curves of transformers, dc machines and induction motors by direct /indirect load tests.
5. Control speed of various dc motor and induction motors.
6. Operate machines in compliance with industry guidelines

List of Experiments:

From following list minimum 8 experiments are to be performed by the student;

1. To perform open circuit (OC) and short circuit (SC) test on single phase transformer to estimate its

core loss, copper loss and equivalent circuit parameters. Verification and analysis of no load current waveform of single phase transformer.
2. To perform direct load test on single phase transformer to obtain its % efficiency and % voltage regulation at various loading conditions.
3. Parallel operation of two single-phase transformers to study their load sharing under various operating conditions.
4. Determination of magnetization or open circuit characteristic and on load external and internal characteristics of a separately excited generator. Determination of efficiency of a separately excited dc generator at various loading conditions.
5. Speed control of a separately dc motor by- (i) armature voltage control and (ii) Field current control method.
6. Direct load test on separately excited dc motor to determine on load Efficiency and speed regulation.
7. To perform load test on three phase squirrel cage induction motor to estimate losses and Efficiency.
8. Perform no load and blocked rotor test on three phase squirrel cage induction motor to estimate its equivalent circuit parameters and efficiency, losses and various torques using circle diagram.
9. To perform no load and blocked rotor test on single phase induction motor to estimate its circuit parameters and various torques.
10. To study and understand the wiring and operation of various Induction motor starters, DOL, Star-Delta, Auto transformer, Soft starters, VFD

[EE 24007] Numerical Methods and Computer Programming

Teaching Scheme	**Examination Scheme**
Lectures:1 Hrs./week	CIE:100
Practical: 2 Hrs/week	In Semester Evaluation: 50 marks
Self-study:1Hrs/week	End Semester Evaluation: 50 marks

Course Outcomes:

At the end of the course, students will be able to

1. Understand the importance and applications of numerical methods.
2. Apply various numerical methods for analysis of Electrical Engineering problems.
3. Solve non-linear equations of higher order which are frequently used in solving practical engineering problems.
4. Apply mathematics in engineering problems.
5. Develop C, C++ or MATLAB/Python programs for numerical methods.

Unit 1 **(2 Hrs)**

Introduction:

Mathematical modeling in engineering problem solving, Approximations and different types of errors, Introduction to MATLAB programming, introduction to Scilab.

Unit 2 **(4 Hrs)**

Simultaneous Algebraic Equations:

Roots of algebraic and transcendental equations, Bracketing methods – bisection method, false

position, Open methods – Newton Raphson, application: Analysis of electrical circuits using above methods,
Cramer's rule, Gauss elimination – pit falls and remedies, Gauss-Seidal, Gauss-Jordan method, Newton Raphson method, Application: solving resistive networks.

Unit 3 **(3 Hrs)**

Curve Fitting:

Interpolation , Extrapolation- Newton's polynomial, Lagrange polynomial

Unit 4 **(5Hrs)**

Numerical Differentiation and Integration:

Euler's method, Modified Euler's method, Runge-kutta methods.
Integration: Trapezoidal rule, Simpson's Rule, Application: calculation of RMS values.

Text Books:

- Steven Chapra, Raymond P. Canale," Numerical Methods for Engineers", Tata McGraw-Hill Education, 8th Edition
- Santosh K. Gupta,"Numerical Methods for Engineers", New Age Publishers, 4th edition.
- S. S. Sastry, "Introductory Methods of Numerical Analysis", Prentice India Learning Pvt. Ltd., 5th edition.

Reference Books:

- E.Bala Guruswamy,"Numerical Methods", Tata McGraw-Hill Education, 2009.
- Rudra Pratap, "MATLAB:An Introduction with Applications", Wiley Publishers, 4th Edition.

e Learning Resources:

- http://www/nptelvideos.in/2012/11/numerical-methods-and-programming.html.
- http://www.nptelvideos.in/11/numerical-methods-and-computation.html.
- https://npte.ac.in/courses/122106033.

Term work:

It shall comprise of minimum 10-12 programs in MATLAB/Phyton/C++ for solving problems demonstrating use of various numerical methods learned in above 6 units.

(AS 24-003) Constitution of India & Universal Human Values

Lecture per week 1 Hr. **In Semester Evaluation: 50 marks**
End Semester Evaluation: 50 marks
CIE 100 marks

Unit	Contents	L
01.	Introduction to The Constitution of India, understanding its objects. Preamble to the constitution of India.Understanding the concept 'Rule of Law', Human Rights and Fundamental Rights.	**3**
02.	Fundamental rights under Part– III, Exercise of the Rights, limitations, and important cases. Fundamental duties & their significance. Relevance of Directive principles of State Policy.	**3**
03.	Legislative, Executive & Judiciary (Union and State Level) Prerogative Writs.Electoral procedure in India	**3**
04.	Constitutional Provisions for Scheduled Castes, Scheduled Tribes, & Backward classes.Constitutional Provisions for Women & Children; Emergency Provisions.	**3**

Amendment procedure and few important Constitutional Amendments

05. Relationship between Law and Ethics,Professional Ethics for Engineers Universal Human Values **2**

Course Outcomes: Students will be able to

CO1: understand the basis of Law, the concept 'Constitution' and the interpretation of the Preamble.

CO2:define the basis of governance of the nation and the fundamental rights.

CO3:illustrate the functioning of the Union and the State Executive

CO4:outline the aspects that allow the use of rights to fulfill one's duties as a responsible citizen.

CO5: Analyze the moral and ethical character needed for a professional engineer.

Suggested learning resources:

1. Introduction to the Constitution of India by DurgaDasBasu (Students Edn.) Prentice – Hall EEE, 19th/20th Edn.
2. Suresh, J. &Raghavan, B.S. (2016). Human Values and Professional Ethics. S. Chand & Company Pvt. Ltd. New Delhi.
3. Engineering Ethics by Charles E.Haries, Michael. S.Pritchard and Michael J.Robins Thompson Asia
4. An Introduction to Constitution of India by M.V. Pylee, Vikas Publishing.
5. Gogate, S. B. (2011). Human Values & Professional Ethics. Vikas Publishing House Pvt. Ltd. New Delhi.

(OE-02) - Principles of Electronic Communication

Teaching Scheme
Lectures:2 Hrs./week
Self Study:1 Hr / week

Examination Scheme
Mid Semester Evaluation- 30 Marks
TA – 20 Marks
End Semester Evaluation - 50 Marks

Course Outcomes

Upon completing this course, the student will be able to:

1. Understand modulation need and techniques in communications and overview of electromagnetic spectrum.
2. Analyze Analog, pulse modulation, and digital modulation techniques.
3. Distinguish Various Local Area Networks and their structure.
4. Conceptualize principles and applications of satellite and optical communications.
5. Understand various cellular telephone systems and wireless technologies.

Unit 1 **(4 Hrs**

Introduction: Need for Modulation, Frequency translation, Electromagnetic spectrum, Gain, Attenuation and decibels.

Unit 2 **(10 Hrs)**

Simple description on Modulation: Analog Modulation-AM, FM, Pulse Modulation-PAM, PWM, PCM, Digital Modulation Techniques-ASK, FSK, PSK, QPSK modulation and demodulation schemes.

Unit 3 **(6 Hrs)**

Telecommunication Systems:

Telephones Telephone system, Paging systems, Internet Telephony.
Networking and Local Area Networks: Network fundamentals, LAN hardware, Ethernet LANs, Token Ring LAN.

Unit 4 **(6 Hrs)**

Satellite Communication:

Satellite Orbits, satellite communication systems, satellite subsystems,
Ground Stations Satellite Applications, Global Positioning systems.
Optical Communication: Optical Principles, Optical Communication Systems, Fiber Optic Cables, Optical Transmitters & Receivers, Wavelength Division Multiplexing.

Unit 5 **(6 Hrs)**

Cellular and Mobile Communications:

Cellular telephone systems, AMPS, GSM, CDMA, and WCDMA. Wireless Technologies: Wireless LAN, PANs and Bluetooth, Zig Bee and Mesh Wireless networks, Wimax and MANs, Infrared wireless, RFID communication, UWB..

Text Books:

- Principles of Electronic Communication Systems, Louis E. Frenzel, 3e, McGraw Hill publications, 2008.
- Electronic Communications systems, Kennedy, Davis 4e, MC Graw Hill Education, 1999.

Reference Books:

- Theodore Rapp port, Wireless Communications - Principles and practice, Prentice Hall, 2002.
- Roger L. Freeman, Fundamentals of Telecommunications, 2e, Wiley publications.
- Introduction to Data Communications And Networking, Wayne Tomasi, Pearson Education, 2005.

EE (EE)-Electrical Installation, Estimation and Costing

Teaching Scheme	**Examination Scheme**
Lectures:3 Hrs./week	Mid Semester Evaluation- 30 Marks
Practcals:4hrs./week	TA – 20 Marks
	End Semester Evaluation - 50 Marks

Course Outcomes:

At the end of this course students will be able to:

1. Interpret the electrical wiring and single line diagrams.
2. Design and construct simple wiring circuits
3. Design and estimate residential and commercial electrical installations as per IE rules
4. Interpret the public Tender document.
5. Design motor control circuits.
6. Understand and comply with electrical codes, regulations, and standards relevant to electrical installations.

Unit 1 **(5 Hrs)**

Electrical components, Symbols and Standards:

Need of electrical symbols, list of symbols, electrical diagrams, methods of representations for wiring diagram, single line diagram of power distribution system, wiring materials, Wires, cables, MCBs, MCCBs, Motor starters, Earthing system, single phase-three phase Energy meter connections, IE Rule

Unit 2 **(5 Hrs)**

Design of Simple Electrical Circuits:

Light and Fan Circuits, Alarm Circuits, Introduction to simple light and fan circuits, design of illumination system for a residential and industrial hall, System of connection of supply and accessories, staircase wiring, Introduction to simple alarm circuits with and without relay, Schematic and wiring diagrams for alarm and signal circuits without relays, Alarm circuit with relays, Design of Small Transformer and Chokes, overload and short circuit protections

Unit 3 **(8 Hrs)**

Design Considerations of Electrical Installations:

Design and Drawing of Panel Boards, Introduction, Design conditions, standard sizes of boards, Electric supply systems, Three phase four wire distribution systems, Protection of electric installation against overload, short circuit and earth fault, Earthing, General requirements and testing of electrical installations, Neutral and earth wire, Types of loads, Systems of wiring, Service connections, Service mains, Sub circuits, Location of outlets, Location of control switches, Location of main board and distribution boards, Load assessment, Guidelines for installation of fittings, Permissible voltage drops and sizes of wires, Estimating and costing of electrical installations.

Unit 4 **(8 Hrs)**

Electrical Installations and Estimates:

Electrical Installations for different types of buildings and small industries, Electrical installations for residential buildings – estimating and costing of material, Electrical installations for commercial buildings, Electrical installations and estimates for small industries.

Unit 5 **(8 Hrs)**

Purchasing techniques:

Spot quotations, floating enquiry, typical example of quotation form, preparation of comparative statement, analysis of comparative statement, tender types(Single tender, Open tender), Earnest money, Security deposit, various steps involved in complete purchase, typical order formats, various criteria for selecting the supply, general considerations in order for procedures to be allowed for submitting the tenders and quotations.

Unit 6 **(8 Hrs)**

Motor Control Circuits:

Starting of 3-phase squirrel cage induction motor, Starting of multi-speed squirrel cage motors, Starting of wound rotor motor, Starting of synchronous motors, Stopping of motors, Contactor control circuit components, Basic control circuits, Motor protection Schematic and wiring diagrams for motor control circuits, Study of Lift/elevator operation – Case study, Study of agricultural motor pump installation- A case study, Study of MCC design using software – A case study.

Text Books:

- S. L. Uppal and G. C. Garg, "Electrical Wiring, Estimating & Costing", Khanna publishers, 6th edition, 2009.
- K. B. Raina and S. K. Bhattacharya, "Electrical Design, Estimating & Costing", New age International Publisher, Reprint, 2009.
- Surjeet Singh, "Electrical estimating and costing", Dhanpat Rai and Co., Second edition, 2001, reprint 2008.

Reference Books:

- Web site for IS Standards.
- Technical manual of Switchgear Industry.

e-Learning resources:

- MPTC-EEE Series of lectures on Industrial Installation Estimation and Costing
- https://www.youtube.com/watch?v=wqQfkIjVwM0&list=PL9ea1TdWq27iPeICoB5HLSH2q9ujv5Fql

[EE] PLCs for Industrial Automation

Teaching Scheme	**Examination Scheme**
Lectures:2 Hrs./week	Mid Semester Evaluation- 30 Marks
Practical:4Hrs/week	TA – 20 Marks
	End Semester Evaluation - 50 Marks

Course Outcomes:

At the end of the course, students will be able to

1. Identify the building blocks and develop architecture for designing a given automation system
2. Develop ladder diagram for a given application
3. Select appropriate PLC and design system for specific application
4. Identify HMI for particular automation examples.
5. Develop skills that are highly relevant to industries employing PLC-based automation systems, such as manufacturing, process control etc.

Unit 1 **(7Hrs)**

Introduction to Industrial Automation:

Importance of Industrial Automation, historical development, Automation Hierarchy, Building blocks of automation systems, description of each component. Types of automation systems:-

fixed and programmable. Different systems for Industrial automation, examples of automation such as cement plant etc., Introduction to various sensors,

Unit 2 **(7Hrs)**

PLC Fundamentals:

Building Blocks of PLC: CPU, Memory organization, Input-output modules (discrete and analog), Special I/O Modules, Power supply. Fixed and Modular PLC and their types, Redundancy in PLC module. I/O module selection criteria Interfacing different I/O devices with appropriate I/O modules.

Unit 3 **(7Hrs)**

PLC Programming:

PLC I/O addressing. PLC programming Instructions: Relay type instructions, timer instructions: Comparison Instructions. Data handling Instructions. Ladder Programming, communications systems such as LAN, CANBUS, Profibus, fieldbus etc

Unit 4 **(7Hrs)**

PLC Applications:

Simple Programming examples using ladder logic: Timer, Motor sequence control, Traffic light control, elevator control, Tank level control, conveyor system, Specifications of various PLC available in the Market

List of Recommended Books:

- Petruzella, F. (2023). Programmable Logic Controllers (6th ed.). Tata-McGraw Hill India.
- Fundamentals of Programmable Logic Controllers , January 2019by Vijay Singh (Author)
- Webb, J. W., & Reis, R. A. (1999). Programmable Logic Controllers: Principles and Applications.
- Erickson, K. T. (2016). Programmable Logic Controllers: An Emphasis on Design and Application.

e-Learning resources:

- Nptel course on Industrial Automation and Control, IIT Kharagpur by Prof. S. Mukhopadhyay, Prof. S. Sen

[MDM- 01] Clean And Green Energy Technology

Teaching Scheme
Lectures:3 hrs./week
Self-study:1 hr/week

Examination Scheme
Mid Semester Evaluation- 30 Marks
TA – 20 Marks
End Semester Evaluation - 50 Marks

Unit 1 **(4 hrs)**

Introduction:

Energy as an indicator of development, World energy scenario, Energy consumption, Type of energy, Future perspective, Indian energy scenario, Energy consumption, Type of energy, Future perspective, Need of clean and renewable energy, Routes for clean energy from fossil fuels, Routes for renewable energy production, Energy conservation

Unit 2 **(5 hrs)**

Solar Energy

Techniques for solar energy conversion to useable form, Solar thermal, Solar photo voltaic, Sun as a source of energy, Solar radiation and spectrum, Solar insulation: Some facts

Unit 3 **(5 hrs)**

Solar Energy Applications

Applications of solar energy, Advantage and disadvantage of solar energy, Techniques for solar energy conversion to useable form: Solar thermal, Solar photo voltaic

Unit 4 **(5 hrs)**

Wind Energy

Wind as a source of energy, Wind energy system, Types of wind machines, Energy production from wind, Wind energy computation, Nature of wind and selection of site

Unit 5 **(6 hrs)**

Wind Mills

Parts of wind mills, Horizontal axis wind mill, Vertical axis wind mill. Rotors of wind mills, Advantage and disadvantage of wind mill, Wind energy in India, Future of wind energy

Unit 6 **(6 hrs)**

Other Renewable Energy Sources

Physical conversion of biomass and wastes for energy use, Densification of biomass and wastes, Tidal Energy, Geothermal Energy.

Text Books:

- Chetan Singh Solanki, "Solar Photovoltaics: Fundamentals, Technologies and Applications", PHI Learning Private Limited, 2012.
- P. Mondal, Technologies for clean and renewable energy production. Available at- https://drive.google.com/file/d/17vQiXJkTt9PqV8emokFJuCgiptyhonxr/view
- S.N.Bhadra, D. Kastha, & S. Banerjee "Wind Electrical Systems", Oxford University Press, 2009
- Rai. G.D, "Non conventional Energy Sources", Khanna publishes, 1993.

Reference Books:

- John Twideu and Tony Weir, "Renewal Energy Resources" BSP Publications, 2006.
- Gray, L. Johnson, "Wind Energy System", prentice hall of India, 1995
- B.H.Khan, " Non-conventional Energy sources", , McGraw-hill, 2nd Edition, 2009.
- Fang Lin Luo Hong Ye, " Renewable Energy systems", Taylor & Francis Group,2013

EXIT OPTIONS

(VSEC)-Electrical Design Software

Course Outcomes:

On successful completion, students will be able to:

1. Model and simulate electrical systems using software tools.
2. Analyze power systems and machines using simulation software.
3. Apply tools for automation, control system design, and circuit simulation.
4. Use scripting and basic programming for electrical applications.

Unit 1: Introduction to Electrical Software Tools

- Overview of software in electrical engineering
- Categories: Simulation, Design, Analysis, and Automation
- Introduction to MATLAB/Simulink, PSpice, ETAP, PSCAD, ANSYS Maxwell

Unit 2: MATLAB and Simulink for Electrical Systems

- MATLAB basics: Arrays, Functions, Scripts
- Simulink: Blocks, Modeling, Scope
- Electrical machine modeling: DC motor, Induction motor
- Power electronics simulations (buck, boost converter)

Unit 3: Circuit Simulation using PSpice / LTSpice

- Basic analog and digital circuit simulation
- AC/DC analysis, transient response
- Operational amplifier circuits
- Power supply and filter design

Unit 4: Power System Simulation using ETAP / PSCAD

- Load flow analysis
- Short circuit analysis
- Relay coordination and protection simulation
- Stability and fault analysis

Unit 5: Control System Design and Automation using LabVIEW / Automation Studio

- Virtual instrumentation in LabVIEW
- Control system simulation: PID tuning
- Industrial automation basics using software
- PLC logic simulation

Unit 6: Finite Element Analysis for Electrical Machines (ANSYS Maxwell)

- Introduction to field simulation
- Magnetic field analysis
- Design and analysis of transformers and motors
- Loss calculation and thermal modeling

Laboratory Work:

- MATLAB/Simulink-based assignments on motor control and power electronics
- Simulation of analog and power circuits using PSpice
- Load flow and fault analysis using ETAP/PSCAD
- Control and automation exercises using LabVIEW/PLC simulator

- Motor simulation using ANSYS Maxwell (2D/3D)

Suggested Software Tools:

- MATLAB / Simulink
- PSpice or LTSpice
- ETAP / PSCAD
- LabVIEW / Automation Studio
- ANSYS Maxwell / COMSOL

Textbooks and References:

1. MATLAB for Engineers – Holly Moore
2. Power System Analysis using ETAP – M. A. Laughton
3. Simulation of Power Electronic Circuits – Muhammad H. Rashid
4. Getting Started with LabVIEW – Robert H. Bishop
5. Finite Element Method for Electrical Engineers – Silvester & Ferrari

(VSEC) Electrical Design and Estimation

Teaching Scheme
Lectures:1 Hr/week
Practicals: 2 hrs./week

Examination Scheme
Mid Semester Evaluation- 30 Marks
TA – 20 Marks
End Semester Evaluation - 50 Marks

Unit 1 **(8 hrs)**

Design Considerations of Electrical Installations:

Electric Supply System, Three phase four wire distribution system, Protection of Electric Installation against over load, short circuit and Earth fault, Earthing, General requirements of Electrical Installations, testing of installations, Indian Electricity rules, Neutral and Earth wire, Types of loads, Systems of wiring, Service connections, Service Mains, Sub-Circuits, Location of Outlets, Location of Control Switches, Location of Main Board and Distribution Board, guide lines for Installation of Fittings, Load Assessment, Permissible voltage drops and sizes of wires, estimating and costing of Electrical installations.

Unit 2 **(3 hrs)**

Electrical Installation of Buildings And Small Industries:

Electrical installations for residential buildings – estimating and costing of material, Electrical installations for commercial buildings, Electrical installations for small industries

Unit 3 **(3 hrs)**

Design of Illumination Schemes:

Introduction, Terminology in Illumination, laws of illumination, various types of light sources, Practical lighting schemes.

List of Experiments:

Students will perform any eight of the following experiments :

1. Study and identification of electrical installation accessories, wiring materials, and protective devices used in buildings.
2. Layout design and wiring of a single-phase residential electrical installation with main switch, MCBs, and earthing.
3. Wiring and testing of a three-phase four-wire distribution system with balanced and unbalanced loads.
4. Measurement of earth resistance using earth tester and verification of effective earthing system.
5. Testing of electrical installations for insulation resistance, polarity, and continuity as per Indian Electricity Rules.
6. Estimation and costing of electrical installation for a residential building using standard schedule of rates.
7. Design, wiring, and testing of electrical installation for a commercial building or small industry.
8. Load assessment and selection of appropriate cable size considering permissible voltage drop.
9. Study and design of illumination scheme for a room using lumen method and calculation

of lighting levels.

10. Comparison of different light sources and evaluation of illumination levels using a lux meter

COEP Technological University Pune

(A Unitary Public University of Govt. of Maharashtra)

School of Engineering and Technology

Curriculum Structure of Third Year

Electrical Engineering

(T.Y. Structure Effective from: A.Y. 2025-26)

T. Y. B. Tech. in Electrical Engineering

Semester-V

Sr. No.	Course Code	Course Title	L	T	P	S	Cr	Category
01	EE-25001	Digital Signal Processing	3	0	0	1	3	PCC
02	EE-25002	Synchronous Machines	3	0	2	1	4	PCC
03	EE-25003	Power System Analysis	3	0	2	1	4	PCC
04	--	Program Specific Elective I	3	0	0	1	3	PEC
05	---	Open Elective–III	2	0	0	1	2	OE
06	EE-25004	Internship	--	--	--	--	1	OJT
07	EE-25005	Project Stage I	--	--	4	--	2	VSEC
08	--	MDM II (Energy Resources, Economics and Environment)	4	0	0	1	4	MDM
		Total	**18**	**00**	**08**	**05**	**23**	

Semester-VI

Sr. No.	Course Code	Course Title	L	T	P	S	Cr	Category
01	*<tbd>*	Power Electronics	3	0	2	1	4	PCC
02	*<tbd>*	Control Systems	3	0	2	1	4	PCC
03	*<tbd>*	Power System Operation and Control	3	0	0	1	3	PCC
04	*<tbd>*	Digital Protection and Switchgear	3	0	2	1	4	PCC
05	*<tbd>*	Program Specific Elective II	3	0	0	1	3	PEC
06	*<tbd>*	(Project Stage II)	0	0	4	--	2	VSEC
07	*<tbd>*	Multidisciplinary Minor – III (Energy Audit and Management)	4	0	0	1	4	MDM
		Total	**19**	**00**	**10**	**06**	**24**	

Program Elective Courses (PECs)

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
PEC/ Sem	Sustainable Mobility	Electrical Machines	Power Systems	Control Systems	Renewable Energy Systems	BEST – E-Mobility (For BEST school students)
PEC - 1/V	Energy Storage Systems EE (PE)25001	Electrical Machine Design	Utilization of Electrical Energy	Mathematical Modelling of Dynamic Systems EE (PE)25002	Energy Economics	Foundation Course, Battery Pack Design and BMS
PEC - 2/VI	Motor Control for Electric Mobility	Analysis of Electric Machinery	High Voltage Engineering	Motor Control for Electric Mobility	Distributed Generation	EV Charger Development and Testing
PEC - 3/VII	Converters for Electric Vehicles	Condition Monitoring of Electrical Machines	Smart Grid Technologies	Intelligent Control	Wind and Solar Energy	Vehicle Dynamics and Testing
PEC - 4/VIII	MOOC Courses offered by NPTEL/SWAYAM					
PEC - 5/VIII	MOOC Courses offered by NPTEL/SWAYAM					
PEC - 6/VIII	MOOC Courses offered by NPTEL/SWAYAM					

Open Electives

Sr. No.	Course Code	Course Title	L	T	P	S	Cr	Category
01	OE – I	Electrical Machines and Drives	2	0	0	1	2	OE
02	OE – II	Principles of Electronic Communication	2	0	0	1	2	OE
03	OEC-25009	Sensors and Actuators	2	0	0	1	2	OE
		Total	**6**	**0**	**0**	**3**	**6**	

Sr. No.	Course Code	Course Title	L	T	P	S	Cr	Category

01	OEC – 25006	Automotive Technology	2	0	0	1	2	OEC
02	OEC – 25002	Environmental pollution	2	0	0	1	2	OEV
03	OEC - 25004	Fundamentals of Machine Learning	2	0	0	1	2	OEC
04	OEC- 25005	Introduction to Aircraft Systems	2	0	0	1	2	OEC
05	OEC- 25001	Materials and Processes for e-Mobility	2	0	0	1	2	OEC
06	OEC - 25007	Operation Research	2	0	0	1	2	OEC
07	OEC- 25008	Reliability Engineering	2	0	0	1	2	OEC
08	OEC- 25011	Urban Development	2	0	0	1	2	OEC

T. Y. B. Tech. in Electrical Engineering

Evaluation Scheme -Semester-V

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
01	PCC	EE-25001	Digital Signal Processing	3	0	0	1	3	30	20	50	50	50
02	PCC	EE-25002	Synchronous Machines	3	0	2	1	4	30	20	50	50	50
03	PCC	EE-25003	Power System Analysis	3	0	2	1	4	30	20	50	50	50
04	PCC	--	Program Specific Elective I	3	0	0	1	3	30	20	50	50	50
05	VEC	---	Open Elective–III	2	0	0	1	2	30	20	50	50	50
06	OE	EE-25004	Internship	--	--	--	--	1	--	--	--	CIE 100	
07	VSEC	EE-25005	Project Stage I	--	--	4	--	2	--	--	--	CIE 100	
08	MDM	--	Energy Resources, Economics and Environment	4	0	0	1	4	30	20	50	--	--
Total				18	00	08	05	23					

[EE-25001] Digital Signal Processing

Teaching Scheme
Lectures: 3 Hrs./week
Self-study: 1 hr/week

Examination Scheme
Mid Sem Evaluation-30 Marks
TA-20 Marks
End Sem Evaluation- 50 Marks

Course Outcomes:
After successful completion of this course students will be able to:

1. solve engineering problems in the area of signal processing.
2. implement FFT algorithms for computing the DFT
3. design FIR and IIR filters.
4. use DSP processor to solve real time application

Unit 1 **[7Hrs]**

Discrete time signals and systems
Importance of DSP, Discrete time signals, classification of discrete time signals and systems, mathematical operations on discrete time signal, response of LTI discrete system, discrete of linear convolution, circular convolution, correlation, crosscorelation, autocorelation Z transform, fourier series and fourier transform.

Unit 2 **[7Hrs]**

Discrete Fourier Transform (DFT)
The DFT and its properties; Inverse DFT, Linear filtering methods based on DFT - Use of DFT in linear filtering, filtering of long data sequences, Efficient computation of DFT algorithms-Radix2 (DIT and DIF), Radix4, Split radix algorithms. Linear filtering approach to computation of DFT-Goertzel algorithm, Chirp z transform, Fast Fourier Transform (FFT

Unit 3 **[6Hrs]**

Digital Filters:
Linear phase FIR filter, characteristic response, location of zeros, Design of FIR filterWindowing, Frequency sampling, Design of IIR filters from Analog filters-Impulse in variance, Bilinear transformation, Matched z-transform.

Unit 4 **[6Hrs]**

Digital Filter Structures:
FIR filters - Direct form, Cascade form, Frequency sampling, Lattice IIR filter - Direct form I, Direct form II cascade form parallel form Lattice and Lattice loader

Unit 5 **[7Hrs]**

Multirate Digital Signal Processing: Decimation by a factor D, Interpolation by a factor I, Sampling rate conversion by a rational factor I/D

Unit 6 **[7 Hrs]**

DSP Processors:
TMS C6xxx, Features, Architecture and Applications. Harvard Architecture, pipelining, Multiplier-Accumulator (MAC) Hardware. Architectures of Fixed- and Floating-point DSP processors. Addressing modes, functional modes. Memory architecture, on-chip peripherals of a DSP processor.

Text Books:
- J. G. Proakisand D. G. Manolakis, Digital Signal Processing - Principles, algorithms and Applications, PHI,2000.
- 2. S. K. Mitra, Digital Signal Processing – A computer Based Approach, MGH, 2010, 4th Edition.
- 3. A. NagoorKeni,Digital Signal Processing , MGH India Pvt. Ltd.

Reference Books:
- Hwei Hsu, "Signals and Systems", 3rd edition, Schaum's series, McGraw Hill, 2013.
- Alan V. Oppenheim, Ronald W. Schafer, "Discrete-Time Signal Processing, 3rd edition, Prentice Hall, 2010.
- B. P. Lathi, "Linear Systems and Signals", 2nd edition, Oxford University Press, 2006.
- S. Salivahanan, "Digital Signal Processing", 2nd edition, McGraw Hill, 2011.

e Learning Resources:
1. Prof. Alan V. Oppenheim, MIT online lecture series on Signals and Systems https://ocw.mit.edu/resources/res-6-007-signals-and-systems-spring-2011/index.htm
2. Prof. Alan V. Oppenheim, MIT online lecture series on Digital Signal Processing https://ocw.mit.edu/resources/res-6-008-digital-signal-processing-spring-2011/
3. Prof. S. C. Datta Roy, IIT Delhi, online lecture series on Digital Signal Processing https://nptel.ac.in/courses/117/102/117102060/

[EE-25002] Synchronous Machines

Teaching Scheme
Lectures: 3 Hrs./week
Self-study: 1 hr/week
Laboratory:2 Hrs/week

Examination Scheme
Mid Sem Evaluation-30 Marks
TA-20 Marks
End Sem Evaluation- 50 Marks

Course Outcomes:
After successful completion of this course students will be able to:

1. compare the constructional features of conventional and modern synchronous machines.
2. select and design armature winding for synchronous machine.
3. analyse the steady state characteristics of synchronous generator
4. analyse the steady state characteristics of synchronous motor
   compute various performance parameters of BLDC, SRM

Unit 1 **[8Hrs]**

Basic concepts in rotating machines

Revision of electromechanical energy conversion principles, AC machines classification, construction, basic principles of operation, MMF of concentrated windings, Magnetic fields in rotating machines, rotating MMF waves in ac machines, generated voltage, torque in no salient pole machines, MMF in linear machines and magnetic saturation, Operation of ac machines, MMF of concentrated and distributed windings, ac machine windings, winding connections, winding factors, modified emf equation, harmonic causes and their suppression.

Unit 2 **[6Hrs]**

Synchronous Generator

Construction, types, circuit model, effects of saliency, determination of synchronous reactance, phasor diagram, power angle characteristics, parallel operation and load sharing, synchronizing process.

Unit 3 **[7 Hrs]**

Synchronous Motor

Synchronous motor, representation, phasor diagram, characteristics curves, torque-speed curves, under and over excitation operation, losses and efficiency, applications

Unit 4 **[7 Hrs]**

Permanent Magnet Synchronous Machines

Permanent magnet synchronous motors, operation, rotor types, equivalent circuit, sine wave motors, air gap flux density, phasor diagram, permanent magnet materials, emf and torque equation, starting, rotor position sensing, speed control, cogging torque, maximum torque, losses and efficiency.

Unit 5 **[7 Hrs]**

Brushless DC motors

Operation of three phase brushless DC motor, construction, rotor types, windings, magnetic circuit analysis, emf and torque equitation, emf waveform, torque and emf constants, speed-torque characteristics, losses and efficiency

Unit 6 **[7 Hrs]**

Switched Reluctance Motor

Introduction to Switched Reluctance Motor, Construction, Poles, phases, windings, static torque equation, energy conversion loop, effects of saturation, Dynamic torque production, Control, shaft position sensing, torque-speed characteristics.

Text Books:

- D. P. Kothari and I. J. Nagrath, "Electric Machines", Tata McGraw Hill Publication, (4th edition reprint 2012).
- A. E. Fitzgerald, C. Kingsley, S. D. Umans, "Electrical Machinery", Tata McGraw Hill, 2002, (6th edition).
- Miller, T. J. E., "Brushless Permanent Magnet and Reluctance Motor Drives", Oxford Science Publications, 1989.
- P. S. Bimbhra, "Electrical Machinery", Khanna Publishers, 7th edition, 2011.

Reference Books:

- Nasser Syed, "Electrical Machines and Transformers", A New York, Macmillon, 1984.
- P. C. Sen., "Principles of Electric Machines and Power Electronics", 2nd Edition, John

Wiley and Sons Inc., 1997.
- Bhag S. Guru and Huseyin R. Hizirouglu, "Electric Machinery and Transformers", 3rd Indian Edition, Oxford University press, Reprint 2014.
- M. G. Say, "Alternating Current Machines", Fifth edition, Low price edition, ELBS, Reprinted 1994
- J. R. Handershot and T.J. E. Miller, "Design of Brushless permanent magnet machines", Book masters Inc. 2010.
- Duane C. Hansalman, "Brushless permanent magnet motor design", second edition, Magna Physics publication, 2006
- K. Venkataratnam, "Special Electrical Machines", Universities press, 2009

e Learning Resources:

- https://nptel.ac.in/courses/108105017; NPTEL: Electrical Engineering, Electrical Machines–I and Electrical Machines -II. Dr. D. Kashta, IIT Kharagpur.
- https://nptel.ac.in/courses/108/105/108105131/ Prof. Tapas Kumar Bhattacharya

e-Book/Notes:

- M. V. Deshpande, "Electrical Machines", PHI Learning Pvt. Ltd. New Delhi, 2011.
- NPTEL web course by Prof. P. Sasidhara Rao, G. Sridhara Rao and Krishna Vasudevan, IIT Madras, https://nptel.ac.in/courses/108/106/108106072/

Synchronous Machines Laboratory

Laboratory: 2 Hrs/week

Examination Scheme:
CIE: 50 Marks
ESE : 50 Marks

Course Outcomes:

After successful completion of this course students will be able to:

1. analyze the construction of synchronous machines.
2. test the synchronous machine to determine its parameters.
3. evaluate steady state performance of synchronous machine.
4. determine the steady state performance of PMSM, SRM, BLDC.

The laboratory should consist of minimum eight experiments based on the following topics:

List of Experiments:

1. Perform O.C. and S.C. test on Alternator: Determination of parameters and regulation of synchronous machine by the EMF method.
2. Perform direct loading test on three phase alternator and determine its performance.
3. Estimate "V" and inverse V" curves of synchronous motor at no load and constant load.
4. Determine the power and load angle curve of synchronous machine.
5. Perform a load test on permanent magnet synchronous motor.
6. Perform a load test on line start permanent magnet synchronous motor.
7. Perform a load test on a BLDC motor.
8. Perform a load test on synchronous reluctance motor.
9. Perform an experiment to control the speed of a brushless DC motor.
10. To study the flux distribution and saturation of Synchronous machine at various loads using FEM package

[EE-25003] Power System Analysis

Teaching Scheme
Lectures: 3 Hrs./week
Self-study: 1 hr/week
Laboratory:2 Hrs/week

Examination Scheme
Mid Sem Evaluation-30 Marks
TA-20 Marks
End Sem Evaluation- 50 Marks

Course Outcomes:

After successful completion of this course students will demonstrate the ability to:

1. familiarize with the various components of the power system, its structure, evolution

and national level scenario
2. evaluate the performance of various transmission line models
3. develop the mathematical model for power system components like generators, transformers etc.
4. compute power flow for the given power system network
5. analyse faults on power system
6. analyse the stability of single/multi machine systems

Unit 1 **[8 Hrs]**

Introduction and Basic Concepts of Power Systems

Structure of power systems, Power system scenario in India, concept of regional and National GRID, overview of conventional and non-conventional power generation. Distribution system, impact of EV and DGs, concept of smart and micro grid, Complex power: concept of real, reactive power and their effects on power system operation, per unit system.

Unit 2 **[7 Hrs]**

Models and Performance of Transmission Line:

Transmission line parameters: Resistance, inductance and capacitance of single phase and three phase line, concept of GMR and GMD, Skin effect, Proximity Effect. Transmission line models -short, medium and long lines, voltage and current waves, surge impedance loading of Transmission Line, Phenomenon of Corona, complex power flow through transmission lines, power transmission capability, Ferranti effect, Tuned power lines, methods of voltage control.

Unit 3 **[8 Hrs]**

Modeling of Power System Components

Synchronous generators: generator model, steady state characteristics, power transformer: Three phase power transformer and its modelling, network model formulation, synchronous machine transients, determination of transient constants, DCcomponent of stator currents.

Unit 4 **[7 Hrs]**

Power Flow Analysis

Power flow equations and solution techniques. Formation of bus admittance matrix, Gauss-Seidel method, Newton-Raphson method, decoupled and fast decoupled methods, comparison of power flow methods, power flow simulation software.

Unit 5 **[6 Hrs]**

Symmetrical and Unsymmetrical Fault Analysis

Internal voltages of loaded machines under transient conditions, selection of circuit breakers, Symmetrical components of unsymmetrical phasors, effect of the transformation on power, sequence impedances and sequence networks of power system, single Line to Ground (LG) faults, Line-to-Line (LL) faults, Double Line to Ground (LLG) faults and open conductor faults.

Unit 6 **[6 Hrs]**

Power System Stability

Steady-state and transient stability concepts, rotor dynamics and swing equation, equal area criterion, step by step solution of swing curve, multi-machine stability, factors affecting transient stability.

Textbooks:

1. Grainger John J and W D Stevenson Jr., "Power system analysis", Mc-Graw Hill.. D. Glover and M. Sarma, "Power System Analysis and Design", (3rd edition), Brooks/ Cole Publishing, 2002.
2. Hadi Sadat, "Power system analysis", McGraw Hill International, 3rd Edition, 2010.
3. J. Nagrath, D. P. Kothari, "Modern Power System Analysis", 4th Edition, Tata McGraw Hill Publishing Co. Ltd., 2011.

Reference Books:

1. O. I. Elgerd, "Electrical energy systems theory: An introduction" Tata McGraw Hill, edition 1999
2. A. R. Bergen and Vijay Vittal, "Power system analysis", (2nd edition), Pearson Education Asia, 2001.

E Resources:

- https://onlinecourses.nptel.ac.in/noc19_ee62/preview

Power System Analysis Laboratory

Teaching Scheme:
Practical: 2 Hrs/week

Examination Scheme:
CIE: 50 Marks
ESE: 50 Marks

Course Outcomes:
After successful completion of this course students will be able to:

1. model power system components for steady state studies.
2. analyze the reactive power requirement of lines and VAR compensation.
3. use MATLAB and ATP/PSCAD for power system studies.
4. analyze the symmetrical and unsymmetrical faults.
5. compute the Y-Bus matrix, perform load flow and interpret the results.

List of Experiments:
Group I: Students will perform an experiment
1. To validate Ferranti effect on an unloaded transmission line.
2. To determine A, B, C, D constants of a given transmission line.
3. To determine the effect of surge impedance loading of a transmission line.
4. To study the Effect of VAR compensation on receiving end voltage profile of distribution line.
5. To determine suitability of cable for AC transmission.
6. To determine the insulator string efficiency.
7. Visit to HV/EHV substation, power generating station.

Group II (minimum four using MATLAB/ PSCAD):
1. Simulation of typical power system- familiarization with generator, line and load models.
2. Formulation of Y-bus matrix using computer program.
3. Computer aided solution of power flow problem by Gauss Siedel/ Newton-Raphson method.
4. To plot the swing curve.
5. Determination of steady state power limit of transmission line.
6. Simulation and analysis for a symmetrical three phase fault by simulation.
7. Simulation and analysis of unsymmetrical faults - LL, LG and LLG.

[OE 3] Sensors and Actuators

Teaching Scheme
Lectures: 2 Hrs./week
Self-study: 1 hr/week

Examination Scheme
Mid Sem Evaluation-30 Marks
TA-20 Marks
End Sem Evaluation- 50 Marks

Course Outcomes:
After successful completion of this course students will be able to:

1. select and specify a sensor actuator system for an application
2. implement a sensor and actuator system for discrete and continuous processes
3. identify the lacunas in the existing sensors selection and suggest improvements
4. troubleshoot the given sensors and actuators systems and commission it in a stipulated time

5. develop a proto-type for effective implementation of automation at level zero Course Contents

UnitI **[6 Hrs]**

Overview of discrete and continuous processes

Characteristics, requirements, specifications, used cases, and cost considerations, block schematic of control loop, various parameters to assess performance

Unit II **[6 Hrs]**

Overview of sensors and Transducers

Case studies based on selection, specifications, installation, commissioning, and troubleshooting of various sensors used for measurement of temperature, pressure, level, and flow

Unit III **[8 Hrs]**

Overview of sensors and Transducers

Case studies based on selection, specifications, installation, commissioning, and troubleshooting of various sensors used for measurement of displacement, velocity, and acceleration

Unit IV **[8 Hrs]**

Implementation case studies

Case studies based on various applications in the area of construction, refrigeration, automotive, and traffic control system

Unit V **[8 Hrs]**

Actuators

Working, designing, selecting, and troubleshooting of pneumatic, hydraulic, and electrical actuators. Case studies comprising of application of actuator knowledge in real life situations and in chosen plants.

Unit VI **[6 Hrs]**

Case studies

Based on various applications and interfacing of sensors in chosen fields, actuators, safety aspects, maintenance and trouble shooting of sensor actuator systems

[EE-25004] Internship

Examination Scheme
CIE- 50 Marks
ESE- 50 Marks

Sr No	Items	Type of Internship to be undertaken
1	Nature of Internship	Industry / R and D labs / Govt Depts/ Education institutes (HEI within 100 NIRF rank) Some of the indicative areas as per Internship Policy are : a) Education institutes / R and D labs/ Incubation centre / Start-up b) Reputed industries c) Economy & Banking Financial Services and Insurance Area d) Logistics, Automotive & Capital Goods Area e) Information Technology/Information Technology enabled Services & Electronics Area f) Handcraft, Art, Design & Music Area

g) Healthcare & Life Science Area
h) Sports, Wellness and Physical Education Area
i) Digitisation & Emerging Technologies
j) Humanitarian, Public Policy and Legal Service Area
k) Food processing industries
l) Sustainable development Area
m) Environment Area
n) Pharmaceutical and textile Industries

2	End Semester Evaluation process	Individual students shall submit a report followed by viva voceby the department panel. Reporting and evaluation format as per template provided by the Nodal Officer, COEP Tech

Internship involves minimum 4 weeks of practical work in the field, technical report writing, and exposure to industry best practices. It aims to bridge the gap between theoretical knowledge and real-world application, fostering professional and personal development. Key elements often include a mini-project, mentorship, and evaluation through viva and term work. Internships emphasize applying technical knowledge to practical situations, fostering an understanding of engineer's responsibilities and ethics.

Key Components of an Internship Syllabus:

1. Practical Work and Project:
Students engage in real-world engineering tasks, often involving a small-scale project aligned with their field of study.
2. Technical Report Writing:
Internships require students to document their experiences, findings, and contributions through comprehensive reports.
3. Industry Exposure:
Internships provide valuable experience in various materials, processes, and quality control aspects within the industry.
4. Mentorship and Guidance:
A faculty mentor from the college and an industry expert act as guides, providing support and feedback throughout the internship.
5. Evaluation:
The internship is evaluated through a viva and a term work component, assessed by both faculty and industry mentors.
6. Internship Diary/Workbook:
Students maintain a detailed diary/workbook to record observations, impressions, and information gathered during the internship.
7.Attendance and Evaluation:
Regular attendance is crucial, and the internship is formally evaluated by the industry supervisor, with a signed and stamped evaluation sheet submitted to the institute.
8. Application of Knowledge to practical problems.

[EE-25005] Project Stage I

Examination Scheme
CIE- 50 Marks
ESE- 50 Marks

Course Outcomes:

After successful completion of this course students will be able to:

1. identify and define an engineering problem based on societal, industrial, or technological needs.
2. conduct an effective literature review and identify research gaps to justify the scope and direction of the project.

3. formulate a structured project plan, team work with time estimation, and task distribution.
4. analyze the feasibility of their proposed solution, considering technical, financial, and sustainability aspects.
5. demonstrate the ability to document and communicate their work effectively through written reports and oral presentations.

The B.Tech project work spans **three consecutive semesters (V, VI, and VII)** to provide students sufficient time to explore, develop, and refine innovative engineering solutions. The project stage I is initiation and planning.

A structured approach using relevant project management tools are to be used for tracking the project work.

1. **Topic Selection:** Choose a feasible project within the domain, addressing a real-world problem, industry need, or research challenge.
2. **Literature Survey:** Conduct in-depth reviews of academic journals, patents, technical papers, and existing systems to identify gaps and opportunities.
3. **Project Planning:** Define objectives, scope, deliverables, and develop a timeline with clear milestones.
4. **Preliminary Design and Methodology:** Formulate the solution approach and outline initial design plans or system architecture.
5. **Deliverables**: Submission of a detailed project synopsis, literature survey documentation, and initial design, along with a presentation.

Sr No	Items	Description of activity
1	**Scope** **(TRL-2)**	Research Problem Identification, Literature, objective, methodology and Architecture / Plan of work
2	**Student project group**	Four students maximum per project. The student group remained the same till the completion of the three stages of the project. No change in topic/ group / guide is allowed in subsequent stages of projects. In case of eventuality, alternate guide may be allotted.
3	**Problem statement identificati -on**	It is mandatory for faculty members to float projects with carefully selected problem statements well in advance. The project should be floated and allotted within a week after the 5th semester registration process is over. Since the project will run for one and half years, it is required by the department to float topics for the choice of students. The project topic should be in line with National Mission / Atmanirbharbharat/ Industry requirements/ Funding body requirements / socially relevant project / Sustainable Development Goals (SDGs)
4	**Project topic selection**	The student group shall choose a project topic amongst the available topics given by the departmentbased on the previous semester CGPA.
5	**Self-Study material for the student**	The department should recommend relevant online / offline self-study materials on IPR, technical paper writing, plagiarism, safety, NDA, Regulatory standards, for example- BIS, etc.
6	**End**	The end semester evaluation shall be based on projectpower point

	Semester Evaluation process	presentation andwell-structured project report. The evaluation shall be done by the panel of at least three members including one of them is project guide.

[MDM II] Energy Resources, Economics and Environment

Teaching Scheme
Lectures: 4 Hrs./week
Self-study: 1 hr/week

Examination Scheme
Mid Sem Evaluation-30 Marks
TA-20 Marks
End Sem Evaluation- 50 Marks

Course Outcomes:
After successful completion of this course, students will demonstrate the ability to

1. Analyse the availability of energy resources and assess methods for quantifying resource depletion and scarcity.
2. Apply basic concepts of economics to energy systems and their impacts.
3. Utilize tools and techniques for project economics from both individual/company and macro-decision-making perspectives.
4. Understand fundamental concepts of welfare economics and environmental economics relevant to energy systems analysis.
5. Evaluate the environmental impacts of energy systems and their associated economic implications.

Unit 1 **[7 Hrs]**
Energy Flow Diagram, Global Trends in Energy Use, India and World- Disaggregation by supply, end use, Energy and Environment, the Kaya Identity, Emission Factor
Energy and Quality of Life, Energy Inequality, Energy Security, Introduction to Country Energy Balance assignment

Unit 2 **[8 Hrs]**
Energy Economics - Simple Payback Period, Time Value of Money- discount rate, Criteria for Assessing Energy Projects –(Net Present Value (NPV), Benefit/Cost Ratio (B/C), Inflation, Internal Rate of Return (IRR)

Unit 3 **[8 Hrs]**
Resources and Reserves Growth Rates in Consumption, Estimates of Duration of Fossil Fuels, McKelvey Diagram, Peak oil, Hubbert's model

Unit 4 **[8 Hrs]**
Materials used in renewable energy (Kuznet's Curve, Betting on the planet, Simon's Change), Non Renewable Energy Economics (Hotelling's Rule)

Unit 5 **[8 Hrs]**
Preferences and Utility, Utility and Social Choice Public and private goods / bads, Demand curves ,Externalities Financing Energy – Debt/ Equity- Sources of funds, innovative financing models Input Output Analysis Primary Energy Analysis, Net Energy Analysis, Examples, Energy Cost of Energy, Life Cycle Analysis of Bioenergy, Net Energy Examples, Energy Policy, Energy Policy Examples, Practice problems solution.

This course is based on Swayam Portal Course by Dr. Rangan Banergy
https://archive.nptel.ac.in/courses/109/101/109101171/

Text Books:
Dr. Rangan Banergee, "Energy Resources, Economics and Environment"
https://drive.google.com/file/d/1Ndn32ykytW2JV2eLHtR1KrqpHzGwTqBM/view

Semester VI

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
1	PCC	*<tbd>*	Power Electronics	3	0	2	1	4	30	20	50	50	50
2	PCC	*<tbd>*	Control Systems	3	0	2	1	4	30	20	50	50	50
3	PCC	*<tbd>*	Power System Operation and Control	3	0	0	1	3	30	20	50	--	--
4	PCC	*<tbd>*	Digital Protection and Switchgear	3	0	2	1	4	30	20	50	50	50
5	PEC	*<tbd>*	Program Specific Elective II	3	0	0	1	3	30	20	50	--	--
6	VSEC	*<tbd>*	(Project Stage II)	0	0	4	--	2	--	--	--	CIE-100	
7	MDM	*<tbd>*	Multidisciplinary Minor –III :Energy Audit and Management	4	0	0	1	4	30	20	50	--	--
			TOTAL	**19**	**00**	**10**	**06**	**24**					

Power Electronics

Teaching Scheme
Lectures: 3 Hrs./week
Self-study: 1 hr/week
Laboratory:2 Hrs/week

Examination Scheme
Mid Sem Evaluation-30 Marks
TA-20 Marks
End Sem Evaluation- 50 Marks

Course Outcomes:
After successful completion of this course students will be able to

1. understand the structure, characteristics, and protection of various power electronics devices and circuits
2. analyse the single phase and three phase AC-DC and AC-AC converters.
3. design different control strategies for various DC-AC converters.
4. identify and design driver circuits and magnetics in various power electronics converters
5. analyse the industry based converters and their performance

Unit 1 **[7 Hrs]**

Power Devices and their properties:
Structure, static and switching Characteristics, Trigger requirements, Ratings, protection and snubber circuit and application of Power diode, SCR, IGBT, Power MOSFET, WBG devices and comparison: GaN, SIC devices, IPM.

Unit 2 **[8 Hrs]**

DC-DC Converter:
MOSFET based choppers: Buck , Boost, Buck-Boost converters, their working, Duty cycle equation, output waveforms, Performance analysis, continuous and discontinuous conduction mode, Voltage Mode Control, Current mode control, Modeling of VM in CCM, Power loss and efficiency calculation.

Unit 3 **[8 Hrs]**

Modern Power Converters:
Hard switched and soft switched converters, ZVS and ZCS Converter, LLC Converter, Phase Shifted full bridge converter, Bidirectional DC to DC converter, Fly back SMPS, Introduction to

EMI/EMC: Basic concepts, sources of EMI, and types of coupling mechanisms. EMC Standards and Regulations**:** CISPR, MIL-STD, FCC

Unit 4 **[8 Hrs]**

AC-DC Converter:

Principle of phase controlled converter, Uncontrolled, semi-controlled and fully controlled converters in single-phase and three-phase configurations. Performance parameters and input-output waveforms for R, R-L loads, harmonic analysis. Improved power quality AC-DC converters (introduction to PFC), Single phase and three phase unity power factor converters.

Unit 5 **[8 Hrs]**

DC-AC Converter:

PWM Inverters: single phase and three phase circuits, principle of operation, performance parameters. Multilevel Inverters: Cascaded H bridge, neutral point clamped. Sinusoidal PWM, Space vector PWM. Algorithm for PWM generation for power converters

Unit 6 **[8 Hrs]**

Driver Circuit and Magnetic Design for PE Converters:

Driver circuit design, ac and dc voltage and current sensing circuits, Heat sink design and selection

Text Books:

1. Ned Mohan, Siddharth Raju, "Simulations and Laboratory Implementations ",Wiley, 2nd Edition, December 19, 2022.
2. P. C. Sen, "Power Electronics", Tata McGraw hill Publication,2nd edition, 2017.
3. M. H. Rashid, "Power Electronics", PHI publication, 3rd edition, 2004.
4. L. Umanand, Power Electronics: Essentials and Applications, Wiley India Pvt. Ltd., 1st Edition, 2009.

Reference Books:

1. Robert W. Erickson and Dragan Maksimović, Fundamentals of Power Electronics, Springer, 2nd Edition, 2001.
2. Keith H. Sueker , "Power Electronic Design: A Practitioner's Guide", Elsevier Publication.
3. Kumar L. Ashok, "Power Electronics with MATLAB", Cambridge University Press.
4. B W Williams, "Power Electronics: Devices, Drivers, Applications and Passive Components", Mac-Millan Publication.
5. Issa Bataresh, Ahmad Harb, "Power Electronics circuit design and analysis", second edition

e-resources:

https://archive.nptel.ac.in/courses/108/102/108102145/

Power Electronics Laboratory

Teaching Scheme
Practical: 2 Hrs/week

Examination Scheme:
CIE: 50 Marks
ESE: 50 Marks

Course Outcomes:

After successful completion of this course students will be able to

1. evaluate the V-I characteristics for different power semiconductor devices.
2. demonstrate the operation and control techniques of power converters.
3. analyze the waveforms exhibited at the input and output ports of the converters.
4. simulate and analyze different converters with their control strategies

List of Experiments:

The laboratory should consist of minimum eight experiments based on the following topics:

1. To evaluate SCR Characteristics, their Turn-on methods.
2. To evaluate IGBT/MOSFET Characteristics, its loss calculations and measurement of

Rds-on and parasitic capacitances including miller capacitor.

3. To evaluate the performance of Single-phase full bridge diode Rectifiers with R and RL load.
4. To evaluate the performance of Single-phase full bridge-controlled Rectifiers with R and RL load.
5. To evaluate the open loop performance of DC-DC buck converter.
6. To evaluate the open loop performance of DC-DC boost converter.
7. To evaluate the open loop performance of DC-DC Flyback back Converter
8. To evaluate the performance of LLC converter.
9. To evaluate the performance of three phase Inverter using different PWM technique.
10. To evaluate the performance of PWM rectifier.

Perform Any two

1. To perform MATLAB/PSIM Simulation of Unity power factor Converter.
2. To perform MATLAB/PSIM Modeling and analysis of DC-DC converter.
3. To perform MATLAB/PSIM Simulation of Multilevel inverter or various PWM strategies.
4. Introduction to LTSPICE circuit simulator

[PCC 14] Control Systems

Teaching Scheme
Lectures: 3 Hrs./week
Self-study: 1 hr/week
Laboratory: 2 Hrs/week

Examination Scheme
Mid Sem Evaluation-30 Marks
TA-20 Marks
End Sem Evaluation-50 Marks

Course Outcomes:

After successful completion of this course students will be able to

1. identify components of control systems.
2. represent the system using transfer function and state space approach.
3. analyze the system performance in both the time and frequency domain.
4. check the stability of the system using time and frequency domain techniques.

apply state feedback control to the given system.

Unit 1 **[6 Hrs]**

Introduction to Control System:

Introduction to control system block diagram, Open loop control and closed loop control, Components of control system, explanation with the help liquid level control system, Significance of actuators and sensors, Types of actuators, Types of sensors, Use of relays, switches and contactors for simple and sequential control system.

Unit2 **[6 Hrs]**

Control System Representation:

Mathematical representation of simple mechanical, electrical, thermal, hydraulic system. Block diagram representation and reduction, Signal flow graph, Transfer function of these systems, Pole zero concepts.

Unit3 **[8 Hrs]**

Time Domain Analysis:

Time response of first order, second order systems. Analysis of steady state error, Type of system and steady state error, Time response specifications, Effect of parameter variation on open loop and closed loop system response, sensitivity, Effect of feedback on system response, stability and disturbance.

Unit4 **[6 Hrs]**

Stability:

Concept of stability, Effect of pole zero location on stability, Routh- Hurwitz criterion. Root

Locus method for analysis of gain margin, phase margin and stability.

Unit5 **[6 Hrs]**

Control System Analysis in Frequency Domain:

Concept of frequency domain behaviour, Bode Plot for analyzing system in frequency domain. Frequency domain performance specifications, Correlation between time domain and frequency domain specification, Nyquist Analysis.

Unit6 **[8 Hrs]**

State Space Approach

Representation of system in state space, Converting transfer function model into state space model. Non uniqueness of state space model, Canonical representation, Eigen values, Solution of state equations, Concept of State feedback control, controllability, Observability.

Text Books:

1. Nagrath and M. Gopal, "Control System Engineering", New Age International Publisher, 8th edition,2009.
2. Norman S. Nice, "Control System Engineering", Wiley,8th edition, 2008.

Reference Books:

1. Smarajit Ghosh, "Control Systems Theory and Applications", Pearson Education, 2nd Edition,2007.
2. Katsuhiko Ogata, "Modern Control Engineering", Prentice Hall,5th Edition, 2010.

e-resources:

NPTEL Course Control Engineering.Prof. M. Gopal (IIT Delhi)

Control System Engineering Laboratory

Teaching Scheme
Practical: 2 Hrs/week

Examination Scheme:
CIE: 50 Marks
ESE: 50 Marks

Course Outcomes:

After successful completion of this course students will be able to

1. analyse the step response of first order and second order system experimentally and by simulation in MATLAB
2. simulate the system to check the stability of system using time domain and frequency domain approaches.
3. simulate the system to evaluate state feedback gain matrix.
4. demonstrate an industrial application (like Bottle filling/Pick and Place control) using PLC

List of Experiments:

The laboratory should consist of minimum eight experiments based on the following topics:

Group I: Students will perform an experiment

1. to study input-output characteristics of various control system components such as potentiometer, relay, stepper motor etc
2. to find time response specifications of electrical system/hydraulic system/pneumatic system/thermal system etc
3. to find transfer function of DC motor.
4. to obtain root locus of DC Motor/ Spring mass damper system

Group II: minimum four simulation experiments using MATLAB/Simulink

1. to plot and analyse the step response of first order and second order system.
2. to study the effect of damping factor zeta on time response performance specifications of first order and second order system.
3. to obtain root locus for a given system and study effect of addition of zero and pole on root locus.

4. to obtain Bode plot and to find the gain margin and phase margin for various systems.
5. to obtain state space representation from transfer function and transfer function to state space.
6. to find Eigen values, and check controllability, observability of the system.
7. to find out feedback gain matrix of state space model of the system.

To study an industrial application (like Bottle filling/Pick and Place control) using PLC.

[PCC 15] Power System Operation and Control

Teaching Scheme
Lectures: 3 Hrs./week
Self-study: 1 hr/week

Examination Scheme
Mid Sem Evaluation-30 Marks
TA-20 Marks
End Sem Evaluation- 50 Marks

Course Outcomes:

After successful completion of this course students will be able to

1. analyze different control strategies for real and reactive power scheduling using control devices.
2. solve problems of economic dispatch, unit commitment using engineering and economic aspects
3. solve power system problems for frequency and voltage control.
4. familiarize with demand side management and electricity markets
5. analyze security aspects of power systems
6. understand various power quality issues and concept of micro-grid.

Unit 1 **[6 Hrs]**

Introduction:

General characteristics of modern power systems, evolution, structure, power system control, operating states of a power system and control strategies, Power System stability Problem, Generator capability curve, AC Transmission.

Unit 2 **[7 Hrs]**

Economic operation of power systems:

Economic dispatch, I/O characteristics, incremental fuel cost curves, economic dispatch without and with transmission losses, penalty factor and participation factor, B-coefficient loss formula, solution of economic dispatch problem using direct method and λ-iteration method, hydro-thermal economic dispatch, co- ordination equations without and with losses, unit commitment using priority list method and dynamic programming, role of load dispatch centres.

Unit 3 **[8 Hrs]**

Voltage and reactive power control:

Need for reactive power control in transmission and distribution systems, control methods in EHV lines, FACTS controllers, HVDC converter, Reactive Power compensation devices: shunt reactors and capacitors, series capacitors, synchronous condensers, tap changing transformers, static VAR systems, voltage profile under variable loading and renewable energy integration, effect of generator excitation adjustment for post disturbance stabilization, voltage collapse, voltage stability and load shedding, Distribution system voltage regulation, Pre fault and post fault power flows.

Unit 4 **[8 Hrs]**

Load frequency control:

Turbine and governor dynamics, load dynamics, need for automatic generation control (AGC), generation control loops and load frequency control (LFC), LFC for single area case, LFC for 2-area case, flat frequency control, tie–line control and tie line bias control, AGC with economic dispatch.

Unit 5 **[6 Hrs]**

Power system security:

Introduction, system state classification in relation to security, security and contingency analysis, state estimation and bad data detection, energy control centres, SCADA systems applications in power networks, wide area monitoring systems (WAMS), PMU, data storage for control, advanced distribution management systems (ADMS).

Unit 6 **[6 Hrs]**

Power System Economics and Recent Developments:

Fundamentals of electricity markets, Market structure and operating mechanisms, Electricity Markets Pricing, Transmission and distribution network pricing, Demand Side management, Introduction to Power Quality, Integration of renewable energy sources, Concept of micro-grid.

Textbooks:

1. Kundur P. and Balu N. J., "Power System Stability and Control", EPRI Series, McGraw-Hill International Book Company,1998
2. Nagrath I. J. and Kothari D. P., "Power System Engineering", 2nd Ed., Tata Mc-Graw Hill Publishing Company,2008
3. C L Wadhwa," Electrical Power Systems",Sixth Ed., New Age International Publishers,2010
4. Wood A. J., Wollenberg B. F. and Sheblé G. B., "Power Generation, Operation and Control", 3rd Ed., John Wiley and Sons, Inc,2014

Reference Books:

1. Grainger J. J. and Stevenson W. D., "Power System Analysis", Tata McGraw-Hill Publishing Company Limited,2008
2. Roger C Dugan and Mark F. McGranahan., "Electrical Power Systems Quality", 2nd Ed., Tata McGraw-Hill Publishing Company Limited.,2010
3. Elgerd O. I., "Electric Energy Systems Theory – An Introduction", 2nd Ed., Tata McGraw-Hill Publishing Company Limited.,2008
4. M. Shahidehpour, H. Yamin, and L. Zuyi, "Market Operations in Electric Power Systems". New York: Wiley, 2002.
5. D. S. Kirschen and G. Strbac, "Fundamentals of power system economics", John Wiley and Sons, 2004

e-resources:

NPTEL Course
Power System Operation and Control Dr. A. Chakrabarti (IIT Kharagpur)
https://archive.nptel.ac.in/courses/108/104/108104052

[PCC 16] Digital Protection and Switchgear

Teaching Scheme	**Examination Scheme**
Lectures: 3 Hrs./week	Mid Sem Evaluation-30 Marks
Self-study: 1 hr/week	TA-20 Marks
Laboratory:2 Hrs/week	End Sem Evaluation- 50 Marks

Course Outcomes:

After successful completion of this course the students will be able to:

1. identify appropriate L.T. and H.T. switchgear for particular application
2. select the different components of protection system such as CT, PT, relays etc.
3. design protection schemes for transformer, generator, transmission lines, bus bar, motors etc.
4. estimate the phasors using different algorithms and design the numerical protection system

Unit 1 **[06 Hrs]**

Circuit Breakers

Circuit Breakers: arc voltage, arc interruption, resistance switching, interruption of capacitive and inductive current, circuit breaker ratings, classification of C.Bs- air break, air blast, vacuum, minimum oil and bulk oil CB, SF_6 C.B. L.T. switchgear:-MCB, MCCB, HRC fuse-construction and application, Circuit breaker selection.

Unit 2 **[07 Hrs]**

Fundamentals of Power System Protection and Over Current Protection

Need of protection, protection principles, protection paradigms-apparatus protection and system protection, desirable attributes of protection. Introduction to C.T., equivalent circuit, C.T. saturation and offset current, V.T. equivalent circuit, Ferro-resonance, Review of calculation of fault currents, fuse protection, over current protection, PSM and TMS setting, phase relay coordination, earth fault protection using over current relays, introduction to directional over-current relays.

Unit 3 **[07 Hrs]**

Numerical Protection

Numerical relaying fundamentals, sampling theorem, anti-aliasing filters, least square method for estimation of phasors, Fourier algorithms, Fourier analysis and discrete Fourier transform, estimation of phasors from discrete Fourier transform, Applications for implantation of various numerical relays. Fundamentals of PMU and WAMS.

Unit 4 **[06 Hrs]**

Transmission System Protection

Introduction to distance relaying, zones of protection, effect of fault arc resistance, directional properties, setting and coordination of distance relays, pilot protection with distance relays ,realization of distance relays using numerical relaying algorithms, Basics of load encroachment and power swing.

Unit 5 **[07 Hrs]**

Protection of Transformer, Generator, Motors

Percentage differential protection, magnetic inrush current phenomenon, percentage differential relay with harmonic restraint, restricted earth fault protection, incipient faults, Buchholz relay, protection against over fluxing. Generator protection: Stator phase and ground fault protection, protection against unbalanced loading ,loss of excitation, loss of prime mover and over speeding, protection of large motors

Unit 6 **[06 Hrs]**

Bus bar protection, Lightning Protection:

Bus bar protection: Different bus bar arrangements, differential protection of bus bar, high impedance differential relay. Lightning and switching over voltages, need and types of lightening arresters, insulation coordination.

Text Books:

1. Fundamentals of power system protection by Y.G. Paithankar, S.R. Bhide., Prentice Hall, India, second edition, 2010.

2. Reference Books:

1. Computer relaying for power systems by A.G. Phadke, J.S.Thorp-research studies press ltd. England John Wiley and sons Inc. New York.
2. Protection of power systems by Blackburn

e-resources:

1. A Web Course on Digital protection of power system by Prof. Dr. S. A. Soman, IIT Bombay.

Digital Protection and Switchgear Laboratory

Teaching Scheme
Practical: 2 Hrs/week

Examination Scheme:
CIE: 50 Marks
ESE: 50 Marks

Course Outcomes:
After successful completion of this course students will be able to

1. understand and simulate the magnetizing current waveform of a single-phase transformer using SIMULINK and practical setup.
2. analyse the transient behaviour of a synchronous machine under sudden short-circuit conditions.
3. examine the working of numerical protection relays such as over-current and earth fault relays.
4. interpret standard impulse voltage waveforms using MATLAB.
5. analyse the restriking voltage waveform using MATLAB and understand its impact on circuit breakers.
6. evaluate the operation of negative phase sequence protection through numerical relay studies.

List of Experiments:
The laboratory should consist of minimum eight experiments based on the following topics:

1. (a) To study magnetizing current waveform of a single phase transformer using SIMULINK.
   (b)To study magnetizing current waveform of a single phase Transformer
2. To study transient by applying sudden short circuit to the synchronous machine
3. To study numerical over-current relay
4. To study micro controller based under/over voltage relay
5. To simulate the generation of standard impulse voltage using MATLAB
6. To simulate the generation of Restriking Voltage Waveform using MATLAB
7. To study numerical earth fault and negative phase sequence relay.
8. To simulate the pilot protection scheme for long transmission lines using communication channels.

[MDM III] Energy Audit and Management

Teaching Scheme
Lectures: 4 Hrs./week
Self-study: 1 hr/week

Examination Scheme
Mid Sem Evaluation-30 Marks
TA-20 Marks
End Sem Evaluation- 50 Marks

Course Outcomes:
After successful completion of this course the students will be able to:

1. formulate energy related problems in the broad areas like electrical and mechanical installations, electrical machines, power systems.
2. plan energy management strategies.
3. Provide energy conservation solutions through energy audit
4. understand the energy billing and financial aspect in energy audit.

Unit 1 **[06 Hrs]**

Energy Scenario
Energy sources-Primary and Secondary, Commercial and Non-commercial, Renewable and Non-Renewable; Energy scenario in India (sector wise consumption, energy needs and integrated energy policy) and Global scenario, Energy Security, Energy and GDP, Energy Intensity on purchasing power parity, Electricity pricing in India, Energy conservation and its

importance

Unit 2 **[06 Hrs]**

Energy Conservation Policies

Salient Features of the Energy Conservation Act, 2001 and, The Energy Conservation (Amendment) Act, 2022, Schemes of BEE under the Energy Conservation Act-2001,Electricity Act, 2003,Integrated Energy Policy, National Action Plan on Climate Change (NPACC)

Unit 3 **[08 Hrs]**

Energy Audit and Management

Energy Audit Definition, Need for Energy Audit, Types of Energy Audit and Approach, Understanding Energy Costs, Benchmarking, Energy Performance, Matching Energy Usage to Requirement, Maximizing System Efficiencies, Optimizing Input Energy Requirements, Fuel and Energy Substitution, Instruments and Metering For Energy Audit, Bureau of Energy Efficiency (the manner and intervals of time for conduct of energy audit) Regulations, 2008; Components of Materials and Energy Balance, Basic Principles of Material and Energy Balance, Classification of Processes.

Unit 4 **[06 Hrs]**

Energy Monitoring

Assessing Energy Profile and Establishing Baseline, Energy Policy and Planning Implementation, Evaluating Energy Performance, Recognize Achievements; What is Monitoring and Targeting, Key Elements of Monitoring and Targeting, Data and Information Sources, Data and Information Analysis, Energy Management Information System (EMIS); Project Development Cycle (PDC), Project Planning Techniques, Implementation Plan for Top Management, Planning Budget

Unit 5 **[06 Hrs]**

Financial and Project ManagementInvestment Need, Appraisal and Criteria, Financial Analysis Techniques; Simple payback period, ROI, Cash Flow, Sensitivity and Risk Analysis, Time value of money ,Net present value,IRR, Breakeven analysis, Energy Performance Contracting and Role of ESCOs, Developing a Typical ESCO Contract, Municipal Energy Efficiency Project through Performance Contracting

Unit 6 **[06 Hrs]**

Global Environmental Issues

Acid Rain, Ozone Layer Depletion, Global Warming and Climatic Change ,International Agreements: United Nations Framework Convention on Climate Change (UNFCCC),The Intergovernmental Panel on Climate Change (IPCC) ,Conference of Parties (COP) ,The Kyoto Protocol, Sustainable Development

Text Books:

1. Guidebooks for National Certification Examination for Energy Manager/Energy Auditors Book General Aspects (available online)
2. Guidebooks for National Certification Examination for Energy Manager/Energy Auditors Book2, Thermal Utilities (available online)
3. Guide books for National Certification Examination for Energy Manager / Energy Auditors Book-3, Electrical Utilities (available online)
4. Guide books for National Certification Examination for Energy Manager Energy Auditors Book-(Available online)

Reference Books:

1. S.C. Tripathy, "Utilization of Electrical Energy", Tata McGraw Hill
2. Success stories of Energy Conservation by BEE, New Delhi (www.bee-india.org).

Project Stage- II

Sr No	Items	Description of activity
1	Scope (TRL-3)	Continuation of Project-I, Planning, fabrication and development of hardware / software and execution; relevant standards.
2	Self-Study material for the student	The department shall recommend relevant online / offline self-study materials on Incubation, Innovation (online / offline)
3	End Semester Evaluation process	The end semester evaluation shall be based on project work in power point presentation and a project report. The evaluation shall be done by the panel of faculty members,at least three members including one of them is project guide.

[PEC-I] Energy Storage Systems

Teaching Scheme
Lectures: 3 Hrs./week
Self-study: 1 hr/week

Examination Scheme:
Mid Sem Evaluation-30 Marks
TA-20 Marks
End Sem Evaluation- 50 Marks

Course Outcomes:
After successful completion of this course, students will be able to:
1. classify energy storage technologies
2. analyze the performance of various Electrical Energy Storage Systems.
3. select the appropriate energy storage system for an application
4. design the battery pack for an application
5. evaluate techno-economic, social and environmental performance with Performance Indicators

Unit 1 **[5 Hrs]**

Energy storage systems overview
Scope of energy storage, needs and opportunities in energy storage, comparison of time scale of storages and applications, Energy storage in the power and transportation sectors.
Importance of energy storage systems in electric vehicles, Current storage business

Unit 2 **[5 Hrs]**

Mechanical Storage System:
Heat pumps, hot water storage tank, CAE , Pumped hydro storage, flywheel energy storage,thermal batteries, application of phase change materials for heat storage-organic and inorganic materials, efficiencies, and economic evaluation of thermal energy storage systems.

Unit 3 **[5 Hrs]**

Chemical Storage System:
Concept of chemical storage of hydrogen etc, application of chemical energy storage system, advantages and limitations of chemical energy storage, challenges, and future prospects of chemical storage systems. Operational principle of a fuel cell, types of fuel cells, hybrid fuel cell-battery systems

Unit 4 **[6 Hrs]**

Electrical storage systems
Working principle of supercapacitor, types of supercapacitors, cycling and performance

characteristics, difference between battery and supercapacitors, hybrid fuel cell-supercapacitor systems, Superconducting magnetic energy storage(SMES), concepts, applications of SME, advantages and limitations of electromagnetic energy storage systems, and future prospects of electrical storage systems.

Unit 5 **[11 Hrs]**

Electro Chemical Storage System:

Working principle of battery, primary and secondary (flow) batteries, comparison of supercapacitor and battery, battery performance evaluation methods, major battery chemistries and their voltages- Li-ion battery and Metal hydride battery vs lead-acid battery.

Unit 6 **[10Hrs]**

Battery Design:

Battery design for transportation, smart battery, Mechanical Design and Packaging of Battery Packs for Electric Vehicles, Charging and discharging mechanism, monitoring and testing of batteries, Thermal management of battery systems, State of Charge and State of Health Estimation Over the Battery Lifespan, Recycling of Batteries, Current chemistry of batteries.

Text books:

- Frank S. Barnes and Jonah G. Levine, Large Energy Storage Systems Handbook (Mechanical and Aerospace Engineering Series), CRC press (2011)
- Ralph Zito, Energy storage: A new approach, Wiley (2010)
- A. G. Ter-Gazarian, Energy Storage for Power Systems, Institution of Engineering and Technology, 2011.

Reference Books:

•Pistoia, Gianfranco, and Boryann Liaw. Behaviour of Lithium-Ion Batteries in Electric Vehicles: Battery Health, Performance, Safety, and Cost. Springer International Publishing AG, 2018.

• Robert A. Huggins, Energy storage, Springer Science and Business Media (2010)

e-learning resources:

https://batteryuniversity.com

NPTEL course on Electric Vehicles and Renewable Energy, By Prof. Ashok Jhunjhunwala, Prof. Kaushal Jha, Prof. L Kannan, Prof. Prabhjot Kaur by IIT Madras

[PEC-I] Electrical Machine Design

Teaching Scheme:
Lectures: 3 Hrs/week
Self-study: 1 hr/week

Examination Scheme:
Mid Sem Evaluation-30 Marks
TA-20 Marks
End Sem Evaluation- 50 Marks

Course Outcomes:

After successful completion of this course the students will be able to:

1. select proper commercial materials, their properties and selection criteria, IS standards used in electrical machine design.
2. design commercial transformers and induction motors as per specifications.
3. apply computer-aided optimization techniques for the design of electrical machines
4. design electrical machines using finite element-based software.

5. analyze electrical machines using finite element-based software

Unit 1 **[06 Hrs]**

Introduction of Electric Machines:

Transformers and three phase induction motors - types, specifications, constructional features, conducting, magnetic and insulating materials, heating and cooling in electrical machines, magnetic circuit calculations.

Unit 2 **[07 Hrs]**

Transformer Design:

Magnetic circuit specific electric and magnetic loading selection, output equation, core and yoke sections, main dimensions design, core loss from design data, winding design, calculations of magnetizing current, winding resistances and leakage reactance's, losses, performance, temperature rise, cooling methods, radiators, tank wall dimensions.

Unit 3 **[06 Hrs]**

Induction Motor Design (Part I):

Output equation, specific electrical and magnetic loading, main dimensions, selection of slots, stator design, stator turns per phase, selection of air gap, unbalanced magnetic pull estimation, harmonic minimization, squirrel cage and wound rotor design, Calculation of magnetic circuit, MMF calculations, stator teeth, stator core, effect of saturation, magnetizing current, no load current and its core loss component, leakage fluxes and reactance calculations, performance calculations - losses, efficiency.

Unit 4 **[07 Hrs]**

FEA based Motor Design :

Induction Motor, BLDC and PMSM Motor, Back emf and torque estimation, Parameter Estimation, Loss Calculations, Design Optimization, Performance and field studies.

Unit 5 **[06 Hrs]**

Fundamentals of Fluid Mechanics and Heat Transfer:

Governing equations (Navier-Stokes, continuity, energy equations), boundary conditions, and physical principles of fluid flow and heat transfer, Numerical Methods in CFD: Discretization techniques (Finite Difference, Finite Volume, Finite Element), mesh generation, stability, and convergence criteria.

Unit 6 **[08 Hrs]**

Thermal Modeling and Simulation FEA Software packages:

Modeling conduction, convection, radiation heat transfer; coupling thermal and fluid flow simulations; validation and applications in engineering problems.

Text Books:

- A. K. Sawhney – "A Course in Electrical Machine Design", 10th Edition, - Dhanpat Rai and sons New Delhi, 2013.
- M. G. Say –The Performance and Design of A.C. Machines, 3rd Edition, CBS Publishers and distributors, Delhi, Reprint 2002.
- S. K. Sen, "Principles of Electrical Machine Design with computer programmes", Oxford and IBH Company Pvt. Ltd. New Delhi, 2006.

Reference Books:

- A. Shanmugasundaram, G. Gangadharan, R. Palani, -Electrical Machine Design Data Book, 3rd Edition, 3rd Reprint, John Wiley Eastern Ltd., New Delhi, 1988.
- K. M. Vishnu Murthy, "Computer Aided Design of Electrical Machines", B.S. Publications, 2008.
- Electrical machines and equipment design exercise examples/ Tutorials using Ansoft's Maxwell 2D machine design package.

e-learning resources

NPTEL Course
Design of Electrical Machines, Prof. Tapas Kumar Bhattacharya (IIT Kharagpur),

[PEC-I] Utilization of Electrical Energy

Teaching Scheme
Lectures: 3 Hrs./week
Self-study: 1 hr/week

Examination Scheme:
Mid Sem Evaluation-30 Marks
TA-20 Marks
End Sem Evaluation- 50 Marks

Course Outcomes:
After successful completion of this course the students will be able to:
1. investigate the various essential requirements and acquire the ability to design a safe and cost-effective electric traction system
2. compare the suitability of different motor drives to be used for a specific purpose
3. analyze the operation of various electric appliances used
3. select appropriate techniques for designing indoor and outdoor lighting schemes
4. apply appropriate techniques, tools and resources in designing/developing electrolytic and electrometallurgical processes
5. design smart electrical heating and welding systems through the use of modern Electrical Engineering and IT tools

Unit 1 [7 Hrs]

Illumination

Nature of light, visibility spectrum curve of relative sensitivity of human eye and wave length of light, Definition: Luminous flux, solid angle, luminous intensity, illumination, luminous efficiency, depreciation factor, coefficient of utilization, space to height ratio, reflection factor, glare, shadow, lux, Laws of illumination, Different type of lamps, construction and working of incandescent and discharge lamps – their characteristics, fittings required for filament lamp, mercury vapour lamp, fluorescent lamp, metal halide lamp, neon lamp, Main requirements of proper lighting; absence of glare, contrast and shadow, General ideas bout street lighting, flood lighting, monument lighting and decorative lighting, light characteristics etc.

Unit 2 [6 Hrs]

Electric Heating

Advantages of electrical heating, Heating methods: Resistance heating – direct and indirect resistance heating, electric ovens, their temperature range, properties of resistance heating elements, domestic water heaters and other heating appliances and thermostat control circuit, Induction heating; principle of core type and coreless induction furnace, Electric arc heating; direct and indirect arc heating, construction, working and applications of arc furnace

Unit 3 [7Hrs]

Electric Welding and Electrolysis

Advantages of electric welding, Welding method, Principles of resistance welding, types, Principle of arc production, electric arc welding, characteristics of arc; carbon arc, metal arc, hydrogen arc welding method of and their applications.

Arc furnaces transformer and welding transformers. Review of electrolytic principles, laws of electrolysis, electroplating, anodizing-electro-cleaning, extraction of refinery metals, power supply for electrolytic process, current and energy efficiency.

Unit-4 [7 Hrs]

Electric Traction

Special features of Traction motors, selection of Traction Motor, Different system of ni traction and their Advantages and disadvantages, Mechanics of train movement: simplified speed time curves for different services, average and schedule speed, tractive effort, specific energy

consumption, factors affecting specific energy consumption, acceleration and braking retardation, adhesive weight and coefficient of adhesion

Unit 5 **[7 Hrs]**

Electric Drives and Elevators

Electric drives : Concept, factors governing selection of electric drives(motor), Types of electrical drives : Individual and Group drive, Applications, Mechanical features of drives: Types and applications various types of enclosures, Transmission of Mechanical Power: Direct and Indirect drive (Belt, Rope, Chain, Gear), Vertical drives and its applications, Bearing: Types and applications, Size and Rating of motor : (Simple numerical on this topic), Load Cycles : Concept with graphical representation, Load equalization, Elevators: Function, Application, types, safety and precautions, case study of latest Elevator, Factors on which shape and size of car depends.

Unit 6 **[6 Hrs]**

Refrigeration and Air conditioning

Electrical Circuits used in Refrigeration and Air Conditioning and Water Coolers: Principle of air conditioning, vapor pressure, refrigeration cycle, eco-friendly Refrigerants, VRF, Centralized air conditioning system, design of AC system for a small room

Text Books:

1. Art and Science of Utilisation of Electrical Energy" by H.Pratab, Dhanpat Raiand Co.
2. "Utilization of electrical energy" by E. O. Taylor.

Reference Books:

1. Gupta, J.B., Utilization of Elect. Energy ,Katariya and sons, New Delhi. •
Garg, G.C., Utilization of Elect. Power and Elect. Traction
2. Hancok N N, Electric Power Utilisation, Wheeler Pub.

e-learning resources:

https://opac.library.iitb.ac.in/cgi-bin/koha/opac-detail.pl?biblionumber=140160

[PEC-I] Mathematical Modelling of Dynamic Systems

Teaching Scheme:
Lectures: 3 Hrs/week
Self-study: 1 hr/week

Examination Scheme:
Mid Sem Evaluation-30 Marks
TA-20 Marks
End Sem Evaluation- 50 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. develop mathematical models of various engineering and physical systems using classical and energy approaches.
2. demonstrate linearization techniques.
3. analyze the models for various practical systems.
4. validate the mathematical models of practical systems using software.

Unit 1 **[6 Hrs]**

Introduction to Modelling: This unit covers the concept of models and their various types. It introduces simulation and various simulation tools. The unit discusses the state space approach, transfer function approach, and methods such as linearization, Lagrangian, and Hamiltonian methods for modelling. Additionally, it includes modelling using first principles.

Unit 2 **[6 Hrs]**

Mathematical Modelling of Physical Systems: Focuses on modelling **[6 Hrs]** mechanical and electrical systems, including analogous systems. It covers system representation using the nodal method, and modelling mechanical components like gear trains, chain drivers, and levers.

Unit 3

Mathematical Modelling of Mechanical Systems: Introduces the basics of heat transfer and mathematical modelling of thermal, pneumatic, and hydraulic systems. The unit also involves analysis of these systems for various types of inputs.

Unit 4 **[6 Hrs]**

Mathematical Modelling of Electrical Systems: Covers fundamentals of electrical system modelling, including mathematical models of RLC circuits. It also focuses on modelling different electrical machines such as DC machines, AC machines, and permanent magnet motors, along with system analysis for various inputs.

Unit 5 **[4 Hrs]**

Mathematical Model of Various Systems: Includes mathematical models of advanced systems such as quadruple and quadrotor systems, magnetic levitation, and simple and inverted pendulum. Faculty may also introduce other significant systems.

Unit 6 **[4 Hrs]**

Bond Graphs Modelling: Introduces bond graph theory and explains the generation of system equations. The unit covers methods of drawing bond graph models for both mechanical and electrical systems.

Text books:

1. K. Ogata, "System Dynamics", Pearson Prentice-Hall, 4th Edition, 2004.
2. M. Gopal, "Modern Control Systems Theory", 2nd Edition, John Wiley, 1993
3. E.O. Doeblin, "System Modeling and Response", John Wiley and Sons, 1980.

Reference books:

1. Desai and Lalwani, "Identification Techniques", Tata McGraw Hill, 1977.
2. Goldstain, "Classical Mechanics"

e-resource:

NPTEL, Modelling and Simulations of Dynamic system by Prof P.M. Phatak, IIT Roorkee

[PEC-I] Energy Economics

Teaching Scheme:
Lectures: 3 Hrs/week
Self-study: 1 hr/week

Examination Scheme:
Mid Sem Evaluation-30 Marks
TA-20 Marks
End Sem Evaluation-50 Marks

Unit 1 **[6 Hrs]**

Energy Economics

Origin and Definitions of Energy Economics, Link between Economics and Energy, Energy Resources and Energy Commodities; Properties of Energy Resources and Energy Commodities, concept of Energy conservation and Energy efficiency. Basics of engineering economics, Role of engineering economics in the decision making process, Economic decisions versus design decisions, discount rate and economic equivalence, present-worth analysis, annual equivalent-worth analysis, rate-of-return analysis, depreciation, and taxation, developing project cash flows, social cost benefit analysis, Origins of renewable energy project risks, sensitivity analysis, break-even analysis, expected value decisions.

Unit 2 **[6 Hrs]**

Demand and Supply of energy

Demand for Energy as a Derived Demand, National Energy consumption, Economic Growth and World Energy Consumption, Demand substitution and energy use Classification of Energy supplies: renewable and non-renewable, Fossil fuels (coal, oil, natural gas), Renewable energy (Hydro, Marine, wind, solar, Geothermal, bio), Nuclear power, Trend and patterns of energy production.

Unit 3 **[8 Hrs]**

Energy Modelling

Review of various energy sector models, energy demand analysis and forecasting, energy supply assessment and evaluation, energy demand – supply balancing, energy modelling in the context of climate change

Unit 4 **[8 Hrs]**

Energy Prices and Markets

Global and National scenario Trend and Patterns of Energy Consumption and the Energy Crisis (since 1970 the Oil shocks and other events),Basic pricing principles, short run versus long run marginal cost pricing, peak load, seasonal, sectoral pricing of electricity, pricing of natural gas and petroleum products, green power markets Energy Pricing and Taxation: Production Cost versus Return on Investment, Models of Pricing, Market Failures, Peak and Off-peak Pricing, Subsidies, The role of regulatory bodies like MERC, Energy Finance: Banks, International organisations, Green Finance initiatives

Unit 5 **[6 Hrs]**

Techno-economic Evaluation of Renewable Energy Technologies:

Technology dissemination models, volume and learning effects on costs of renewable energy systems, dynamics of fuel substitution by renewable energy systems and quantification of benefits, fiscal, financial and other incentives for promotion of renewable energy systems and their effect on financial viability, case studies on financial feasibility evaluation of renewable energy devices and systems. Renewable energy economy policy

Unit 6 **[5 Hrs]**

Sustainable Development and Energy Policy

Concept of Sustainable Development and SDGs, Energy Security: India's initiatives, Energy and Climate Change, Energy Efficiency and carbon emissions: Global and National trends, Energy Policy The Economics of Climate Change, Climate Change Background, Overview of GHG Emissions, Economic Approach to Control the Greenhouse Effect, Options to Cope with Global Warming, Generic Options, National Policy Options, Emissions Trading System (ETS)

Text Books:

1. Bhattacharyya, S C. (2011), Concepts, Issues, Markets and Governance, Springer Kandpal T.C. & Garg, H.P. (2003),Financial Evaluation of Renewable Energy Technologies, Macmillan India Park
2. C. S., Kim, G., & Choi, S. (2007). Engineering Economics. Pearson Prentice Hall, New Jersey.
3. Thuesen, G. J., &Fabrycky, W. J., (2002). Engineering economy. Prentice Hall of India.

Reference books:

1. Belli, P., Anderson, J., Barnum, H., Dixon, J., & Tan, J. P. (1998). Handbook on economic analysis ofinvestment operations. The World Bank, Washington,
2. DC. Dahl, C. (2015). International Energy Markets: Understanding Pricing, Policies, & Profits.
3. PennWell Books. Desai, V. (1997). Guidelines for the economic analysis of projects. Asian Development Bank.
4. Gittinger, J. P.(1973), Economic Analysis of Agricultural Project, The Johns Hopkins University Press. Jebaraj, S., & Iniyan, S. (2006). A review of energy models. Renewable and Sustainable Energy Reviews, 10(4),281-311.
5. Kaplan, S. (1983). Energy economics: quantitative methods for energy and environmental decisions.McGraw-Hill College.

e-resource:

https://s3.ap-south-1.amazonaws.com/aipnpc.org/downloads/T_5052_ENERGY_EFFICIENCY_IN_ELECTRICAL_UTILITIES_BOOK_03.pdf

[PEC-II] Motor Control for Electric Mobility

Teaching Scheme:
Lectures: 3 Hrs/week
Self-study: 1 hr/week

Examination Scheme:
Mid Sem Evaluation-30 Marks
TA-20 Marks
End Sem Evaluation-50 Marks

Course Outcomes:

After successful completion of this course the students will be able to

1. describe the architecture of electric vehicles and the role of motor control systems in electric mobility applications.
2. compare different types of electric motors (DC, BLDC, Induction, PMSM) based on their characteristics and suitability for electric vehicle applications.
3. analyze various motor control strategies such as scalar control, vector control, and field-oriented control (FOC).
4. implement motor drive systems using simulation tools and/or hardware platforms
5. evaluate the performance of electric drive systems under different loading and operating conditions

Unit 1 **[6 Hrs]**

Fundamentals of Electric Mobility and Motors

Introduction to Electric Mobility: Trends, types of EVs (BEV, HEV, PHEV),Overview of EV Powertrain, Need for Efficient Motor Control in EVs ,Review of Electric Machines: DC Machines, AC Machines,Motor Characteristics: Torque-speed curves, efficiency

Unit 2 **[6 Hrs]**

DC and BLDC Motor Control

Brushed DC Motor: Operation, control methods (voltage control, PWM) , BLDC Motor: Construction, operation, commutation techniques, Open-loop vs. Closed-loop Control of BLDC , BLDC applications in electric mobility.

Unit 3 **[5 Hrs]**

AC Motor Control – Induction Motors (IM)

Construction, working, and characteristics of Induction Motors, Control Techniques: Scalar control (V/f), Vector control (introduction), Slip, torque, and efficiency in IM, Pros and cons of IM for EV applications.

Unit 4 **[5 Hrs]**

Permanent Magnet Synchronous Motor (PMSM) Control

PMSM vs BLDC: Similarities and differences, Field-Oriented Control (FOC): Theory and implementation, Sensor-based vs. Sensorless Control, Applications in EVs, e-bikes, drones

Unit 5 **[6 Hrs]**

Motor Drives and Power Electronics Interface

Overview of Motor Drives (DC-DC, DC-AC converters),Inverters: Topologies and operation
PWM techniques: Sine PWM, SVPWM, Regenerative braking and energy recovery.

Unit 6 **[6 Hrs]**

Integration, Applications, and Case Studies

Motor selection criteria for EV applications, Integration of motor, drive, and controller
Case studies on LMVs, HMVs, Reliability, thermal design, and efficiency mapping.

Text Books:

1. Dr. P. S. Bimbhra, Generalized Theory of Electrical Machines, Fifth edition, Khanna publishers
2. P.C.Krause, Oleg Wasynczuk, Scott D. Sudhoff, Analysis of Electrical Machinery and Drive systems, 3rd Edition, 2013 Wiley, IEEE Press.
3. Electric Motor Drives: Modeling, Analysis, and Control , R. Krishnan ,Pearson Education, 2001, ISBN: 9780130910149
4. Modern Electric Vehicle Technology , C. C. Chan, K. T. Chau ,Oxford University Press

,2001,ISBN: 9780198504160
5. Electric Machines and Drives: A First Course , Ned Mohan ,Wiley , 2011 , ISBN: 9781118074817
6. Electric Drives for Electric Vehicles ,K.T. Chau , IET (The Institution of Engineering and Technology), 2015 ,ISBN: 9781849198208

Reference books

Power Electronics: Converters, Applications, and Design ,Ned Mohan, Tore M. Undeland, William P. Robbins ,Wiley , 2003 (3rd Edition), ISBN: 9780471226932

e-resource

NPTEL Course Electrical Machines - II (Dynamic modeling of machines) Prof. G. Sridhara Rao, IIT Madras

(PEC-III) Analysis of Electric Machinery

Teaching Scheme:
Lectures: 3 Hrs/week
Self-study: 1 hr/week

Examination Scheme:
Mid Sem Evaluation-30 Marks
TA-20 Marks
End Sem Evaluation-50 Marks

Course Outcomes:

After successful completion of this course the students will be able to:
1.analyze electromechanical devices and machines
2.use reference frame theory to study and analyze the behavior of induction and synchronous machines
3.calculate the machine inductances for use in machine analysis
4.model the electrical machine from the terminal junction with transmission systems

Unit 1 **[4 Hrs]**

MODELING CONCEPTS

Basic Two-pole machine representation of commutator machines 3- phase - phase synchronous machine without damper bars and 3 phase induction machine Kcron primitive machine voltage, current and torque equations. Real time model of a two-phase induction machine transformation to obtain constant matrices. Three phases to two phase transformation power invariances.

Unit 2 **[6 Hrs]**

REFERENCE FRAME THEORY and PM AC MACHINE:

Introduction–Background–Equations of Transformation stationary circuit variables transformed to the Arbitrary Reference Frame, – Commonly Used Reference Frames Balanced Steady -State Phasor Relationships, Balanced Steady-State Voltage Equations PM AC Machine: Voltage and Torque equations in Machine Variables and Rotor Reference Frame Variables

Unit 3 **[6 Hrs]**

DC Machines Modelling:

Mathematical model of a separately excited DC motor, Steady state and transient analyses Transfer function of a separately excited DC machine, Mathematical model of a DC series motor, shunt motor- linearization techniques for small perturbations.

Unit 4 **[6 Hrs]**

Dynamic Analysis of Synchronous Machine:

Synchronous machine inductances, voltage equations in the rotor's dq0 reference frame, electromagnetic torque-current in terms of linkages, Dynamic performance of synchronous, machine, three-phase fault, comparison of actual and approximate transient torque characteristics, Equal area criteria, simulation of three phase synchronous machine, Dynamic performance during a sudden change in input torque, Torque vs. rotor angle characteristics

Unit 5 **[5 Hrs]**

Modeling of Three Phase Symmetrical Induction:
Generalized model in an arbitrary reference frame, Electromagnetic torque– Derivation of commonly used induction machine models, Stator reference frame model, Rotor reference frame model, Synchronously rotating frame model, Equations in flux linkages, per unit model-Dynamic Simulation, Small signal equations of induction machine,derivation of dq flux linkage model.

Unit 6 **[5 Hrs]**

Modelling of Reluctance Machines
Introduction to Reluctance Machines, Magnetic Circuit and Inductance Modeling , Dynamic Modeling, Torque Production and Characteristics, Reluctance Machines Models, Applications and Recent Developments.

Text Books:

1. P. C. Krause, "Analysis of Electric Machinery", McGraw Hill, 3rd edition, New York, 1987.
1. Chee Mun Ong, "Dynamic simulation of Electrical Machinery using Matlab/Simulink" Prentice Hall PTR, 1st edition, 1997.
2. P. Vas, "Vector Control of A.C. Machines", Clarendon Press, 1st edition, Oxford 1990.
   Reference Books:
3. J .M. D. Murphy and F.G. Turnbull, "Power Electronic Control of AC motors", Pergamum Press, 1st edition, 1988.
4. W. Leonhard, "Control of Electrical Drives", Springer Verlag, 3rd edition, 1985.

[PEC-IV] High Voltage Engineering

Teaching Scheme;
Lectures: 3 Hrs./week
Self-study: 1 hr/week

Examination Scheme:
Mid Sem Evaluation-30 Marks
TA-20 Marks
End Sem Evaluation-50 Marks

Course Outcomes (COs):
After successful completion of this course the students will be able to:

1. propose the proper insulating medium / system; based on the insulation strength of the material for applying to high voltage systems.
2. measure the high voltages and currents.
3. design the high voltage laboratory and the equipment installations in it.
4. carry out HV tests on various equipments e. g. Cables, CBs, Insulators etc, using relevant testing IS and be able to give analysis of the test results

Unit 1 **[05 Hrs]**

Breakdown in Gases:
Breakdown in Uniform gap, non-uniform gaps, Townsend's theory, Streamer mechanism, Corona discharge

Unit 2 **[04 Hrs]**

Breakdown in liquid and solid Insulating materials: Breakdown in pure and commercial liquids, Solid dielectrics and composite dielectrics, intrinsic breakdown, electromechanical breakdown and thermal breakdown, Partial discharge, applications of insulating materials.

Unit 3 **[04 Hrs]**

Generation of High Voltages:
Generation of high voltages, generation of high alternating voltages, generation of impulse voltages, generation of impulse currents, tripping and control of impulse generators.

Unit 4 **[04 Hrs]**

Measurements of High Voltages and Currents:
Peak voltage, impulse voltage and high direct current measurement method, cathode ray

oscillographs for impulse voltage and current measurement, measurement of dielectric constant and loss factor, partial discharge measurements

Unit 5 **[03 Hrs]**

Design, Planning and Layout of H. V. Laboratories:

High voltage laboratory layout, indoor and outdoor laboratories, testing facility requirements, High Voltage laboratories all over the world

Unit 6 **[04 Hrs]**

High Voltage Testing of Electrical Apparatus:

Various standards for HV Testing of electrical apparatus, IS, ANSI, IEC standards, Testing of insulators and bushings, testing of isolators and circuit breakers, testing of cables, power transformers and some high voltage equipment.

Text Books:

1. High Voltage Engineering by M. S. Naidu, V. Kamaraju, Tata McGraw Hill Publication Co. Ltd New Delhi, 2013, ISBN-978-1-25-906289-6
2. High Voltage Engineering by C. L. Wadhwa, New Age International Publishers Ltd.
3. High Voltage Engineering by Prof. D. V. Razevig Translated from Russian by Dr. M. P. Chourasia Khanna Publishers, New Delhi 67

Reference Book:

1. High Voltage Engineering Fundamentals by E. Kuffel, W. S. Zaengl, J. KuffelNewnes Publication, ISBN-0-7506-3634-3
2. High Voltage and Electrical Insulation Engineering by Ravindra Arora, WolfGangMosch New Age International Publishers Ltd. Wiley Eastern Ltd., ISBN-978-0-470- 60961-3
3. Various IS standards for HV Laboratory Techniques and Testing

e-resources:

NPTEL Course on High Voltage Engineering
Prof. Subba Reddy B, IIT Madras

(PEC-V) Distributed Generation

Teaching Scheme:
Lectures: 3 Hrs/week
Self-study: 1 hr/week

Examination Scheme:
Mid Sem Evaluation-30 Marks
TA-20 Marks
End Sem Evaluation-50 Marks

Course Outcomes (COs):

After successful completion of this course the students will be able to:

1. explain the principles, classification, and benefits of distributed generation technologies.
2. analyze various renewable energy technologies such as solar PV, wind, and biomass for DG applications.
3. understand power electronic converters and storage systems used in DG.
4. assess the performance of DG integration on power quality, protection, and reliability.
5. evaluate technical, regulatory, and economic issues related to DG systems.
6. interpret emerging trends such as microgrids, IoT, and peer-to-peer energy trading.

Unit 1 **[4 Hrs]**

Introduction to Distributed Generation

Concept and need for distributed energy generation, Centralized vs. decentralized generation Classification of DG technologies: renewable and non-renewable, Benefits: reliability, resilience, efficiency, environmental technical challenges in integration

Unit 2 **[8 Hrs]**

Renewable Energy Technologies for DG

Solar PV Systems: Operating principles, I-V and P-V curves, MPPT techniques, PV

configurations: standalone, grid-connected, hybrid Design aspects and performance modeling Wind Energy Systems: Wind turbine types, power curves, site selection Wind generators: Squirrel cage, DFIG, PMSG Grid integration aspects.Other DG Sources: Biomass, small hydro, fuel cells, diesel generators, Working principles and applications.

Unit 3 **[6 Hrs]**

Power Electronics and Energy Storage for DG

Overview of power converters: DC-DC, DC-AC, AC-DC, Voltage source and current source inverters Control of inverters: frequency, voltage, and reactive power Energy storage technologies: batteries, supercapacitors Hybrid energy systems and energy management strategies.

Unit 4 **[6 Hrs]**

Grid Integration, Power Quality, and Protection

Operating modes: grid-connected, islanded, Synchronization techniques Standards and codes: IEEE 1547, IEC 61727, CEA regulations, Power quality issues: harmonics, flicker, voltage sags, Protection: anti-islanding, fault detection, coordination.

Unit 5 **[6 Hrs]**

Technical and Economic Evaluation of DG

Impact of DG on voltage profile, losses, and system reliability, Reactive power capabilities and VAR support, Economic analysis: CAPEX, OPEX, LCOE, payback period, Tariff mechanisms: net metering, TOD, feed-in tariffs.

Unit 6 **[6 Hrs]**

Policy, Regulation, and Emerging Trends:

National and international DG policies and regulatory frameworks, Renewable purchase obligations (RPOs), incentives, Smart grid and microgrid concepts, Emerging technologies: IoT, blockchain, AI in DG systems, Peer-to-peer energy trading and virtual power plants

Textbooks

1. G. M. Masters, Renewable and Efficient Electric Power Systems, 3rd Edition, Wiley, 2021.
2. M. H. J. Bollen and F. Hassan, Integration of Distributed Generation in the Power System, Wiley-IEEE Press, 2011.

Reference Books

1. John Twedell and Tony Weir, Renewable Energy Resources, 4th Edition, Routledge, 2021.
2. Mukund R. Patel and Omar Faruque, Wind and Solar Power Systems: Design, Analysis, and Operation, 3rd Edition, CRC Press, 2021.
3. IEEE Std 1547-2018, Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces.
4. M. C. Chandorkar, Distributed Generation and Microgrid, Oxford University Press, 2020.

e-resources

NPTEL Course

Distributed Generation and Renewable Energy Integration, Prof. Ashish Pathak, NIT Delhi

BEST SCHOOL PECs- e-Mobility

[PEC– VI] a) Introduction to Engineering Measurements and Safety
b) Introduction to Advanced Test Equipment
c) Battery Pack Design and BMS

Teaching Scheme
Lectures: 2 hrs./week
Practicals: 4 hrs./week

Examination Scheme
Mid Sem Evaluation-30 Marks
TA-20 Marks

Self Study: 1 hrs / week End Sem Evaluation-50 marks

Course Outcomes: (a)

At the end of the course, students will demonstrate the ability to

1.Explain the fundamentals of measurement, units, standards, and types of errors.
2.Apply safety procedures and first-aid practices in electrical laboratories and industry.
3. Interpret safety regulations and standards such as IS, IEC, IEEE, OSHA, and CEA.
4. Evaluate earthing methods and measure earth resistance as per IS and IEC codes.
5. Identify and operate measuring instruments used for electrical safety.
6. Select and use appropriate Personal Protective Equipment (PPE) in electrical laboratories.

Course Outcomes: (b)

1. Understand the operation and application of advanced electrical test equipment.
2. Perform accurate measurements using oscilloscopes, power analyzers, electronic loads, and emulators.
3. Apply correct measurement techniques for AC sources, DAQ systems, and LabVIEW.
4. Interpret test results and validate equipment performance against standards.
5. Demonstrate safe and correct usage of advanced electrical test systems.

Course Outcomes: (c)

1.Understand Li-ion battery characteristics, charging behavior, and performance limitations.
2. Model cells and battery packs including electrical, thermal and aging aspects.
3. Analyze thermal management challenges and design appropriate cooling strategies.
4. Explain the functions and architecture of BMS including SoC, SoH, balancing, and protection.
5. Describe the battery packaging process including cell grading, welding, integration and testing.

Unit 1 (7hrs)

(covers Part a)

Measurement, Units & Standards: Definition and importance of measurement; SI units; calibration; accuracy; precision; errors; minimization.
Safety Practices: Electrical hazards – shock, burns, arc flash; LOTO; first aid.
Safety Regulations: IS, IEC, IEEE, ANSI, OSHA; CEA guidelines; safety audits.
Earthing & Standards: Plate, pipe, rod earthing; earth resistance; IS:3043 code.
Measuring Instruments: Earth tester; insulation tester; measurement principles.
PPE: Gloves, helmets, mats, arc suits; selection; IEC standards.

Unit 2 (7hrs)

(Covers Part b)

Data Acquisition (DAQ) – architecture, sensors, signal conditioning, NI DAQ modules.

Virtual Instrumentation concepts – virtual panels, GUI-based measurement, measurement automation.

Electronic Loads – programmable DC electronic loads, constant current/voltage/resistance/power modes.

Programmable AC Sources – voltage/frequency programming, THD control, harmonic simulation.

Grid Emulators – utility simulation, fault simulation, EV-grid testing applications.

Battery Emulators – programmable voltage-current profiles, EV charger testing applications.

Regenerative Test Systems – energy regeneration, high-efficiency test benches.

Introduction to LabVIEW – front panel, block diagram, dataflow programming, simple DAQ applications.

Unit 3 **(8hrs)**

(Covers Part c)

Introduction to Li-ion Batteries: Types of cells – cylindrical, prismatic, pouch, Li-ion chemistries – NMC, LFP, NCA, LCO, battery characteristics – OCV, internal resistance, capacity, charging behavior – CC/CV, significance of C-rate, desired EV battery specifications – energy, power, lifecycle, safety.

Unit 4 **(10hrs)**

Battery Pack Modelling: Cell electrical models – Rint model, Thevenin model, HPPC Test – purpose and procedure, extraction of resistance and capacity, SOC, temperature and aging impact, battery pack modelling – series/parallel configuration, cell balancing requirements, thermal impact on battery performance and safety.

Unit 5 **(9hrs)**

Thermal Management of Batteries: Heat generation mechanisms in Li-ion cells, cooling approaches – air cooling, liquid cooling, PCM-based cooling, refrigerant cooling, thermal runaway – causes, detection and mitigation strategies, thermal interface materials, effects of temperature on safety, cycle life and performance.

Unit 6 **(10hrs)**

Battery Management System (BMS): Functions of BMS – monitoring, estimation, protection and communication, SoC estimation – Coulomb counting, voltage-based estimation and EKF methods, SoH and RUL basics, balancing – passive and active methods, communication protocols – CAN, LIN, SPI, I2C, safety protection features – overcurrent, overcharge, overdischarge and thermal protections.

Unit 7 **(8 hrs)**

Battery Packaging Process: Cell grading – voltage, IR and capacity tests, sorting procedures, spot welding – nickel strip selection and weld quality, module assembly – busbars, insulation, mechanical fixtures, BMS integration and wiring harness, battery pack validation – capacity testing, thermal testing, vibration testing and safety certification tests.

Textbooks:

(Part a)

- A.K. Sawhney, Electrical and Electronic Measurements and Instrumentation, Dhanpat Rai & Co., 19th Edition, 2011.
- Alan S. Morris, Measurement and Instrumentation Principles, Elsevier, 3rd Edition, 2011.
- John Cadick et al., Electrical Safety Handbook, McGraw-Hill, 4th Edition, 2012.
- S. Rao, Testing, Commissioning, Operation & Maintenance of Electrical Equipment,
- Khanna Publishers, 8th Edition, 2017.
- B.L. Theraja, A Textbook of Electrical Technology Vol 1, S. Chand, 23rd Edition, 2005.

(Part b)

- Gary W. Johnson & Richard Jennings, LabVIEW Graphical Programming, McGraw-Hill, 4th Edition, 2006.
- National Instruments, LabVIEW for Everyone, Prentice Hall, 3rd Edition, 2006.
- Sanjay Gupta & Joseph John, Virtual Instrumentation Using LabVIEW, McGraw-Hill, 2nd Edition, 2017.
- Keysight Technologies, Application Handbook for Power Supplies, Electronic Loads, and Emulators, Keysight, 2020.
- Chroma Systems Solutions, Programmable AC Sources, DC Sources, and Electronic Loads – Application Guide, Chroma, 2019.

- Tektronix, Fundamentals of Power Electronics Testing and Measurement, Tektronix Application Note, 2018.

(Part c)

- Gregory L. Plett, Battery Management Systems (Volumes 1–3), Artech House, 2015–2021.
- Davide Andrea, Battery Management Systems for Large Lithium-Ion Battery Packs, Artech House, 2010.
- Rui Xiong, Lithium-Ion Batteries: Advanced Models, Diagnostics and Control, Elsevier, 2020.
- Isidor Buchmann, Batteries in a Portable World, Cadex Electronics, 4th Edition, 2016.
- Mohammad B. Shadmand& Bikash C. Pal, Battery Systems Engineering, Wiley, 2013.
- IEC/ISO Standards: IEC 62660, ISO 12405 – EV Battery Testing Standards.

a) Introduction to Engineering Measurements and Safety Laboratory

b) Introduction to Advanced Test Equipment Laboratory

c) Battery Pack Design and BMS Laboratory

Teaching Scheme	**Examination Scheme**
Practical: 4hr / week	CIE:100 Marks

Course Outcomes: (Part a)

1. Perform fundamental electrical and mechanical measurements.
2. Evaluate earth and insulation resistance as per standards.
3. Demonstrate safe working and PPE usage.
4. Calibrate instruments and analyze measurement errors.
5. Prepare structured laboratory reports

Experiments: (Part a)

1. Measurement using Digital Vernier Calipers and Micrometer.
2. Measurement of Earth Resistance using Earth Tester.
3. Measurement of Insulation Resistance using Megger.

Experiments: (Part b)

1. Conduct a simple load test using programmable electronic loads
2. Conduct a simple load test using regenerative test systems
3. Testing of battery charger using battery emulator
4. Conduct a simple load test using programmable AC source

Experiments: (Part c)

1. Experimental extraction of cell parameters and mathematical modelling of a cell
2. Charging characteristics of a single cell for multiple C-ratings

3. Thermal simulation of a cell & EV battery pack using Ansys
4. Thermal shock test for battery pack
5. Evaluation of State of Charge (SoC) balancing techniques
6. Functional testing of BMS
7. Comparative evaluation of coulomb counting and Kalman filter-based SoC estimation
8. Capacity evaluation of a battery pack
9. Hands-on in Battery packaging Process

Exit option to qualify for B. Voc. :

- Internship of 8 weeks

Final Year B. Tech. in Electrical Engineering

Semester -VII

Sr. No	Course Code	Course Title	L	T	P	S	Cr	Category
01	PCC-17	Electric Drives	3	0	0	1	3	PCC
02	PCC-14	Control System Design	3	0	2	1	4	PCC
03	PEC-03	Program Specific Elective III	3	0	0	1	3	PEC
05	RM	Research Methodology	2	0	0	1	2	RM
06	OJT-02	Internship	-	-	-	--	1	OJT
07	VSEC- 03	(Project Stage III)	0	0	4	--	5	VSEC
08	MDM- 04	Multidisciplinary Minor –IV Multidisciplinary Project	2	0	0	2	3	MD M
Total			**13**	**00**	**06**	**06**	**21**	

Seester –VIII

Sr. No.	Course Code	Course Title	L	T	P	S	Cr	Category
01	OJT-03	Internship	-	-	-	--	3	OJT
01	PEC-04	Program Specific Elective IV MOOC- I	3	0	0	--	3	PEC
01	PEC-05	Program Specific Elective V MOOC- II	3	0	0	--	3	PEC
02	PEC-06	Program Specific Elective VI MOOC- III	3	0	0	--	3	PEC
Total			**09**	**00**	**00**	**00**	**12**	

Additional Credits for Exits

After Completion of Second Year

Sr. No.	Course Code	Course Title	L	T	P	Cr	Category
01	VSEC- 02	Electrical Design Software	1	0	4	3	VSEC
02	VSEC- 03	PLC for Industrial Automation	1	0	4	3	VSEC
		Total	**02**	**00**	**08**	**06**	

INTERNSHIP-III (after semester VI, summer internship)		
Sr. No.	**Items**	**Type of Internship to be undertaken**
1	Nature of Internship	Industry / R and D labs / Education institutes (HEI less than 100 NIRF rank) This should be decided by the nature of Project-I selected by the group of students in the 5th semester. A project guide should assist in grooming the student group in relevant areas to enhance their knowledge and skills.
2	End Semester Evaluation process	Individual student / Group of students shall submit a report followed by viva voce by the department level faculty members on the project report prepared by them. A template for report writing and evaluation format will be provided by the Nodal Officer, COEP Tech.
INTERNSHIP-IV, (semester VIII)		
Sr No	**Items**	**Type of Internship to be undertaken**
1	**Nature of Internship**	Industry / R and D labs / Education institutes (less than 100 NIRF) / International Internship / Replacement
2	**Scope of internship**	a) The project student group can pursue innovation (TRL > 4) on carry forward ideas / Proof of concept derived from Project -III for scaling up the model/ prototyping/ product development / Start-up. OR b) Students can pursue international internship abroad / Preplacement / Internship in Industry / Education institutes (less than 100 NIRF) / R and D labs
2	**End Semester Evaluation process**	Students shall submit Internship report followed by voce viva, power point presentation by the department level faculty members. A template for report writing will be provided by the Nodal Officer, COEP Tech.

[VSEC] Course Title: Electrical Design Software

Duration:16 weeks – 8 Hrs/Day

Level: Undergraduate Professional Certificate
Prerequisites: S.Y. (Electrical)

Basic Knowledge of Electrical Engineering
And Circuit Theory

Course Outcomes:

After successful completion of this course the students will be able to:

1. Develop proficiency in using industry-standard electrical design softwares for schematic drafting, simulation, and system analysis.
2. Understand and apply electrical engineering principles to design and analyze real-world electrical systems including power distribution, control panels, and automation circuits.
3. Interpret and generate technical documentation
4. Simulate and analyze power system behavior under various conditions using tools like ETAP or PSCAD, including load flow, short circuit, and protection coordination.
5. Design and execute a capstone project that demonstrates integration of software tools to solve practical electrical engineering problems in industrial or utility applications.

Unit 1 **24Hrs**

Introduction to Electrical Design and CAD Tools

- Overview of Electrical Design Workflow
- Types of Electrical Design (Power Systems, Control Systems, etc.)
- Introduction to CAD in Electrical Engineering
- Software Overview: AutoCAD Electrical, ETAP, MATLAB Simulink, EPLAN, PSCAD, etc.

Unit 2 **24Hrs**

AutoCAD Electrical

- Basics of AutoCAD Interface
- Creating and Editing Electrical Schematics
- Working with Symbols, Components, and Wires
- PLC I/O Drawings
- Generating Reports and Bill of Materials (BOM)
- Project and Panel Layouts

Unit 3 **22Hrs**

ETAP (Electrical Transient Analyzer Program)

- ETAP Interface and One-Line Diagrams
- Load Flow Analysis
- Short Circuit Analysis
- Motor Starting Analysis
- Protection Coordination
- Arc Flash Analysis
- Case Studies

Unit 4 **22Hrs**

MATLAB & Simulink for Electrical Systems

- Basics of MATLAB for Electrical Engineers
- Simulink Environment Overview
- Modeling of Electrical Circuits and Systems

- Power Electronics Simulation
- Control Systems Design
- Real-Time Simulation Concepts

Unit 5 **22Hrs**

EPLAN Electric P8

Project Setup and Data Management

- Wiring and Device Configuration
- Creating Panel Layouts
- PLC Configuration
- Integration with Manufacturing

Unit 6 **26Hrs**

Industry Applications and Mini-Project

- **Industrial Electrical Design Practices**
- Standards and Compliance (IEC, IEEE, NEC)
- Documentation and Quality Assurance
- Mini-Project using one or more software tools
  (Example: Substation design, Control panel layout, Renewable energy system modeling)

e-resources:

- https://www.advanceelectricaldesign.com
- solidedge.siemens.com

MOOCs Identified – NPTEL- PEC-05, 06,07

Sr. No	Course Name	Weeks	Level	NOC URL
1	DC Microgrid and Control System	12	UG	https://onlinecourses.nptel.ac.in/noc20_ee84/preview
2	Electrical Distribution System Analysis	12	UG	https://onlinecourses.nptel.ac.in/noc19_ee61/preview
3	Electrical Equipment And Machines: Finite Element Analysis	12	UG	https://onlinecourses.nptel.ac.in/noc20_ee81/preview
4	Control And Tuning Methods In Switched Mode Power Converters	12	UG	https://archive.nptel.ac.in/courses/108/105/108105180/
5	Power System Dynamics, Control And Monitoring	12	UG	https://onlinecourses.nptel.ac.in/noc21_ee16/preview
6	Design And Simulation of DC-DC Converters Using Open-Source Tools	12	UG	https://archive.nptel.ac.in/noc/courses/noc16/SEM1/noc16-ec07/
7	Industrial Automation And Control	12	UG	https://archive.nptel.ac.in/courses/108/105/108105062/
8	High Power Multilevel Converters - Analysis, Design And Operational Issues	12	UG	https://archive.nptel.ac.in/courses/108/102/108102157/
9	Data Analytics using Python	12	UG	https://nptel.ac.in/noc/courses/noc20/SEM1/noc20-cs46/

10	Linear Dynamical Systems	12	UG	https://onlinecourses.nptel.ac.in/noc20_ee47/preview
11	Linear System Theory	12	UG	https://archive.nptel.ac.in/courses/108/106/108106150/
12	Deep Learning	12	UG	https://nptel.ac.in/noc/courses/noc19/SEM2/noc19-cs54
13	Embedded System Design with ARM	12	UG	https://nptel.ac.in/noc/courses/noc20/SEM1/noc20-cs15/
14	Electrical Equipment and Machines: Finite Element Analysis	12	UG	https://onlinecourses.nptel.ac.in/noc24_ee91/