B.Tech.

IN

ELECTRICAL AND ELECTRONICS ENGINEERING

CURRICULUM

AND

SYLLABI

(Applicable from 2023 Admission onwards)

तमसो मा ज्योतिर्गमय

Department of Electrical Engineering
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
Kozhikode – 673 601, KERALA, INDIA

The Program Educational Objectives (PEOs) of
B.Tech in Electrical and Electronics Engineering

PEO1	To prepare under graduate students to excel in technical profession/ industry and/or higher education by providing a strong foundation in mathematics, science and engineering.
PEO2	To transform engineering students to expert engineers so that they could comprehend, analyse, design and create novel products and solutions to Electrical and Electronics Engineering problems that are technically sound, economically feasible and socially acceptable
PEO3	To train students to exhibit professionalism, keep up ethics in their profession and relate engineering issues to address the technical and social challenges.
PE04	To develop communication skills and team work and to nurture multidisciplinary approach in problem solving

Programme Outcomes (POs) and Programme Specific Outcomes (PSOs) of B.Tech in Electrical and Electronics Engineering

PO1	**Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2	**Problem analysis**: Identify, formulate, research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3	**Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
PO4	**Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO5	**Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.
PO6	**The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
PO7	**Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8	**Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9	**Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10	**Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO11	**Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12	**Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PSO1	Identify, formulate and analyse real-life electrical and electronics engineering problems by way of utilising the knowledge of mathematics, science and engineering principles.
PSO2	Design and develop sophisticated equipment and experimental systems for carrying out detailed investigation to multifaceted electrical and electronics engineering problems leading to reliable and feasible solutions for the same utilising all the available tools.
PSO3	Work as an electrical or electronics engineer who is capable of identifying solutions to various local and global problems faced by the society, up keeping a pollution free environment without compromising professional ethics and social values.
PSO4	Think independently, take initiative, lead a team of engineers or researchers, communicate orally as well as in writing with others, participate in various professional activities, take up administrative responsibilities and thus maintain lifelong learning process.

CURRICULUM

Total credits for completing B.Tech in Electrical and Electronics Engineering is 153.

COURSE CATEGORIES AND CREDIT REQUIREMENTS:

The structure of B.Tech programmes shall have the following Course Categories:

Sl. No.	Course Category	Number of Courses	Minimum Credits
1.	Institute Core (IC)	8	22
2.	Program Core (PC) and Program Electives (PE)	36-37	91
3.	Open Electives (OE)	6	18
4.	Institute Electives (IE) (Entrepreneurship Innovation (EI) + Digital / Automation Technologies (DA) + Humanities, Social Science, Management (HM))	6	18
5.	Activity Credits (AC)	--	4

COURSE REQUIREMENTS

The effort to be put in by the student is indicated in the tables below as follows:
L: Lecture (One unit is of 50-minute duration)
T: Tutorial (One unit is of 50-minute duration)
P: Practical (One unit is of one-hour duration)
O: Outside the class effort / self-study (One unit is of one-hour duration)

1. INSTITUTE CORE (IC)

a) Mathematics

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	MA1001E	Mathematics I	3	1	0	5	3
2.	MA1011E	Mathematics II	3	1	0	5	3
3.	MA2001E	Mathematics III	3	1	0	5	3
4.	MA2011E	Mathematics IV	3	1	0	5	3
		Total	**12**	**4**	**0**	**20**	**12**

b) Basic Sciences and Drawing

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	PH1003E	Electricity and Magnetism	3	0	0	6	3
2.	CE1011E	Engineering Graphics	2	0	2	5	3
		Total	**5**	**0**	**2**	**11**	**6**

c) Professional Communication and Professional Ethics

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	MS1001E	Professional Communication	3	1	0	5	3
2.	EE1004E	Professional Ethics	1	0	0	2	1
		Total	**4**	**0**	**0**	**7**	**4**

2A. PROGRAMME CORE (PC)

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	EE1001E	Introduction to Electrical Engineering	3	1	0	5	3
2.	EE1002E	Electrical Measurements	3	0	0	6	3
3.	EE1003E	Electronic Circuits - I	3	1	0	5	3
4.	EE1091E	Basic Electrical Engineering Lab	0	0	2	1	**1**
5.	EE1011E	Circuits and Networks	3	1	0	5	3
6.	ME1401E	Engineering Mechanics	3	0	0	6	3
7.	EE1012E	Digital Circuits and Systems	3	1	0	5	3
8.	EE1092E	Electrical Measurements Lab	0	0	2	1	1
9.	EE2001E	Signals and Systems	3	1	0	5	3
10.	EE2002E	Microprocessors and Microcontrollers	2	1	2	4	3
11.	EE2003E	Electrical Machines -I	3	1	0	5	3
12.	EE2004E	Electronic Circuits – II	3	1	0	5	3
13.	EE2091E	Electronics Lab – I	0	0	2	1	1
14.	ME2011E	Mechanical Engineering	3	0	0	6	3
15.	EE2011E	Power Systems - I	3	1	0	5	3
16.	EE2012E	Power Electronics	3	1	0	5	3
17.	EE2013E	Electrical Machines -II	3	1	0	5	3
18.	EE2014E	Control Systems -I	3	1	0	5	3

19.	EE2092E	Electrical Machines Lab – I	0	0	2	1	1
20.	EE2093E	Electronics Lab – II	0	0	2	1	1
21.	EE3001E	Digital Signal Processing	3	1	0	5	3
22.	EE3002E	Power Systems - II	3	1	0	5	3
23.	EE3003E	Control Systems - II	3	1	0	5	3
24.	EE3004E	Analog Integrated Circuits	3	0	0	6	3
25.	EE3091E	Power Electronics Lab	0	0	2	1	1
26.	EE3092E	Electrical Machines Lab – II	0	0	2	1	1
27.	EE3011E	Introduction to Communication Systems	3	0	0	6	3
28.	EE3012E	Instrumentation Systems	2	1	2	4	3
29.	EE3093E	Electrical Engineering Drawing	1	0	1	2	2
30.	EE3094E	Project	0	0	0	9	3
31.	EE3095E	Power Systems Lab	0	0	2	1	1
32.	EE3096E	Control Systems Lab	0	0	2	1	1
33.	EE4091E	Summer Internship	0	0	0	6	2
34	EE4092E	Project	0	0	0	9	3

2B. LIST OF ELECTIVES

Following courses may be credited under the categories mentioned in the table below, in addition to the Programme Electives.

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Additional Categories			
								PE	EI	DA	HM
Program Elective- I (PE-I)											
1.	EE4021E	Advanced DC – AC Power Conversion	3	0	0	6	3	Y	N	N	N
2.	EE4022E	Switched-mode Power Supplies	3	0	0	6	3	Y	N	N	N
3.	EE4023E	Power Semiconductor Devices	3	0	0	6	3	Y	N	N	N
4.	EE4024E	Power Electronic Drives	3	0	0	6	3	Y	N	N	N
Program Elective- II and III (PE-II and III)											
1.	EE4021E	Advanced DC – AC Power Conversion	3	0	0	6	3	Y	N	N	N
2.	EE4022E	Switched-mode Power Supplies	3	0	0	6	3	Y	N	N	N
3.	EE4023E	Power Semiconductor Devices	3	0	0	6	3	Y	N	N	N
4.	EE4024E	Power Electronic Drives	3	0	0	6	3	Y	N	N	N
5.	EE4025E	Optimal and Adaptive Control	3	0	0	6	3	Y	N	N	N

6.	EE4026E	Power System Stability and Control	3	0	0	6	3	Y	N	N	N
7.	EE4027E	Flexible AC Transmission	3	0	0	6	3	Y	N	N	N
8.	EE4028E	Switchgear and Protection	3	0	0	6	3	Y	N	N	N
9.	EE4029E	Electricity Markets	3	0	0	6	3	Y	N	N	N
Electives towards OE-I to OE-VI, DA, HM											
1.	EE2021E	Python Programming and Applications	3	0	0	6	3	N	N	Y	N
2.	EE2022E	Introduction to C Programming	3	0	0	6	3	N	N	Y	N
3.	EE3021E	Digital Control Systems	3	0	0	6	3	N	N	N	N
4.	EE3022E	Electrical Machine Design	3	0	0	6	3	N	N	N	N
5.	EE3023E	Dynamic Analysis of Electrical Machines	3	0	0	6	3	N	N	N	N
6.	EE3024E	Electrical System Design for Buildings	3	0	0	6	3	N	N	N	N
7.	EE3025E	Digital CMOS Integrated Circuits	3	0	0	6	3	N	N	N	N
8.	EE3026E	Electrical Engineering Materials	3	0	0	6	3	N	N	N	N
9.	EE3027E	Dynamic System Simulation	3	0	0	6	3	N	N	N	N
10.	EE3028E	Network Analysis	3	0	0	6	3	N	N	N	N
11.	EE3029E	Optimization Techniques and Algorithms	3	0	0	6	3	N	N	N	N
12.	EE3030E	Artificial Neural Networks and Fuzzy Logic Systems	3	0	0	6	3	N	N	N	N
13.	EE3031E	Special Machines and Linear Machines	3	0	0	6	3	N	N	N	N
14.	EE3032E	Electric Power Utilization	3	0	0	6	3	N	N	N	N
15.	EE3033E	Biomedical Engineering	3	0	0	6	3	N	N	N	N
16.	EE3034E	Illumination Engineering	3	0	0	6	3	N	N	N	N
17.	EE3035E	Linear System Theory	3	0	0	6	3	N	N	N	N
18.	EE3036E	Data Structures and Algorithms	3	0	0	6	3	N	N	Y	N
19.	EE3037E	LT and HT Distribution Systems	3	0	0	6	3	N	N	N	N
20.	EE3038E	Digital System Design	3	0	0	6	3	N	N	N	N
21.	EE3039E	Advanced Processor Architecture and System Organisation	3	0	0	6	3	N	N	N	N
22.	EE3040E	Electric Vehicle System Engineering	3	0	0	6	3	N	N	N	N
23.	EE3041E	Heuristic Methods for Optimization	3	0	0	6	3	N	N	N	N

24.	EE3042E	Computer Control of Industrial Processes	3	0	0	6	3	N	N	N	N
25.	EE3043E	Bio-Signal Processing	3	0	0	6	3	N	N	N	N
26.	EE3044E	System Identification and Parameter Estimation	3	0	0	6	3	N	N	N	N
27.	EE3045E	High Voltage Engineering	3	0	0	6	3	N	N	N	N
28.	EE3046E	Embedded Systems	3	0	0	6	3	N	N	Y	N
29.	EE3047E	Introduction to Data Science	3	0	0	6	3	N	N	Y	N
30.	EE3048E	Machine Learning and Deep Learning – Fundamentals and Applications	3	0	0	6	3	N	N	N	N
31.	EE3049E	Introduction to Data Analytics	3	0	0	6	3	N	N	N	N
32.	EE3050E	Grid Integration of Renewable Energy	3	0	0	6	3	N	N	N	N
33.	EE3051E	Industrial Automation	3	0	0	6	3	N	N	Y	N
34.	EE3052E	Fundamentals of Artificial Intelligence	3	0	0	6	3	N	N	N	N
35.	EE3053E	Soft Computing	3	0	0	6	3	N	N	Y	N
36.	EE4021E#	Advanced DC – AC Power Conversion	3	0	0	6	3	Y	N	N	N
37.	EE4022E#	Switched-mode Power Supplies	3	0	0	6	3	Y	N	N	N
38.	EE4023E#	Power Semiconductor Devices	3	0	0	6	3	Y	N	N	N
39.	EE4024E#	Power Electronic Drives	3	0	0	6	3	Y	N	N	N
40.	EE4025E#	Optimal and Adaptive Control	3	0	0	6	3	Y	N	N	N
41.	EE4026E#	Power System Stability and Control	3	0	0	6	3	Y	N	N	N
42.	EE4027E#	Flexible AC Transmission	3	0	0	6	3	Y	N	N	N
43.	EE4028E#	Switchgear and Protection	3	0	0	6	3	Y	N	N	N
44.	EE4029E#	Electricity Markets	3	0	0	6	3	Y	N	N	N
45.	EE4030E#	Power System Operation and Control	3	0	0	6	3	N	N	N	N
46.	EE4031E#	Non-linear System Analysis	3	0	0	6	3	N	N	N	N
47.	EE4032E#	Analog MOS Circuits	3	0	0	6	3	N	N	N	N
48.	EE4033E#	Power Quality	3	0	0	6	3	N	N	N	N
49.	EE4034E#	Static VAR Compensation and Harmonic Filtering	3	0	0	6	3	N	N	N	N
50.	EE4035E#	Smart Grid Engineering	3	0	0	6	3	N	N	N	N
51	EE4036E#	Advanced Digital Signal Processing	3	0	0	6	3	N	N	N	N

52.	EE4037E#	Control and Guidance Engineering	3	0	0	6	3	N	N	N	N
53.	EE4038E#	Economic Evaluation of Power Projects	3	0	0	6	3	N	N	N	Y
54.	EE4039E#	Hydrogen Economy	3	0	0	6	3	N	N	N	Y

Available for students who have reached fourth level.

3. OPEN ELECTIVES (OE)

Courses offered by Other Departments/Schools/Centres or Approved Online Platforms, with a limit on the maximum number of courses from such platforms specified as per B.Tech Ordinances and Regulations. In addition, PE courses offered by the Parent department shall be included in this category for students of the Parent department.

4. INSTITUTE ELECTIVES (IE)

In case of the Institute Electives, courses in the appropriate categories offered by other departments/schools/centres also can be credited instead of the courses offered by the **Department of Electrical Engineering**, subject to the approval from the Course Faculty and Faculty Advisor.

a) Entrepreneurship / Innovation Basket (EI):

Courses proposed by the Departments/Schools/Centres and approved by Institute Innovation Council. Total credits required is 3.

b) **Digital Automation Technologies (DA):**

Courses related to programming / automation tools & techniques / Industry 4.0. Total credits required is 6.

c) Humanities, Social Science, Management (HM):

Courses such as Indian and Foreign languages, Economics, Engineering Management, Financial Management and Design Thinking. Total credits required is 9.

5. ACTIVITY CREDITS (AC)

A minimum of 80 Activity Points are to be acquired for obtaining the 4 Activity Credits required in the curriculum.

Activity points acquired should be a minimum of 20 at the end of S4.
Activity points acquired should be a minimum of 40 at the end of S6.

Curriculum for B. Tech
in Electrical and Electronics Engineering

PROGRAMME STRUCTURE

Semester I

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MA1001E	Mathematics I	3	1	0	5	3	IC
2.	CE1011E	Engineering Graphics	2	0	2	5	3	IC
3.	EE1001E	Introduction to Electrical Engineering	3	1	0	5	3	PC
4.	EE1002E	Electrical Measurements	3	0	0	6	3	PC
5.	EE1003E	Electronic Circuits - I	3	1	0	5	3	PC
6.	EE1004E	Professional Ethics	1	0	0	2	1	IC
7.	EE1091E	Basic Electrical Engineering Lab	0	0	2	1	1	PC
		Total	**15**	**3**	**4**	**29**	**17**	**--**

Semester II

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MA1011E	Mathematics II	3	1	0	5	3	IC
2.	PH1003E	Electricity and Magnetism	3	0	0	6	3	IC
3.	MS1001E	Professional Communication	3	1	0	5	3	IC
4.	EE1011E	Circuits and Networks	3	1	0	5	3	PC
5.	ME1401E	Engineering Mechanics	3	0	0	6	3	PC
6.	EE1012E	Digital Circuits and Systems	3	1	0	5	3	PC
7.	EE1092E	Electrical Measurements Lab	0	0	2	1	1	PC
		Total	**18**	**4**	**2**	**33**	**19**	**--**

Semester III

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MA2001E	Mathematics III	3	1	0	5	3	IC
2.		Digital / Automation Technologies - I	3	0	0	6	3	IE
3.		E /I Elective	3	0	0	6	3	IE
4.	EE2001E	Signals and Systems	3	1	0	5	3	PC
5.	EE2002E	Microprocessors and Microcontrollers	2	1	2	4	3	PC
6.	EE2003E	Electrical Machines -I	3	1	0	5	3	PC
7.	EE2004E	Electronic Circuits – II	3	1	0	5	3	PC
8.	EE2091E	Electronics Lab – I	0	0	2	1	1	PC
		Total	**20**	**5**	**4**	**37**	**22**	

Semester IV

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MA2011E	Mathematics IV	3	1	0	5	3	IC
2.	ME2011E	Mechanical Engineering	3	0	0	6	3	PC
3.	EE2011E	Power Systems - I	3	1	0	5	3	PC
4.	EE2012E	Power Electronics	3	1	0	5	3	PC
5.	EE2013E	Electrical Machines -II	3	1	0	5	3	PC
6.	EE2014E	Control Systems -I	3	1	0	5	3	PC
7.	EE2092E	Electrical Machines Lab – I	0	0	2	1	1	PC
8.	EE2093E	Electronics Lab – II	0	0	2	1	1	PC
Total (Excluding the Minor Courses)			**18**	**5**	**4**	**33**	**20**	

Semester V

Sl. No	Course Code	Course Title	L	T	P	O	Credits	Category
1.	EE3001E	Digital Signal Processing	3	1	0	5	3	PC
2.	EE3002E	Power Systems - II	3	1	0	5	3	PC
3.	EE3003E	Control Systems - II	3	1	0	5	3	PC
4.	EE3004E	Analog Integrated Circuits	3	0	0	6	3	PC
5.		Humanities - I	3	0	0	6	3	IE
6.		Digital / Automation Technologies - II	3	0	0	6	3	IE
7.	EE3091E	Power Electronics Lab	0	0	2	1	1	PC
8.	EE3092E	Electrical Machines Lab – II	0	0	2	1	1	PC
Total (Excluding the Minor Courses)			**18**	**3**	**4**	**35**	**20**	

Semester VI

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	EE3011E	Introduction to Communication Systems	3	0	0	6	3	PC
2.	EE3012E	Instrumentation Systems	2	1	2	4	3	PC
3.		Open Elective - I (OE-I)	3	0	0	6	3	OE
4.		Open Elective - II (OE-II)	3	0	0	6	3	OE
5.		Humanities - II	3	0	0	6	3	IE
6.	EE3093E	Electrical Engineering Drawing	1	0	2	3	2	PC
7.	EE3094E	Project	0	0	0	9	3	PC
8.	EE3095E	Power Systems Lab	0	0	2	1	1	PC
9.	EE3096E	Control Systems Lab	0	0	2	1	1	PC
Total (Excluding the Minor Courses)			**15**	**1**	**8**	**42**	**22**	

Semester VII

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.		Humanities -III	3	0	0	6	3	IE
2.	EE40XXE	Program Elective- I (PE-I)	3	0	0	6	3	PE
3.		Open Elective –III (OE-III)	3	0	0	6	3	OE
4.		Open Elective -IV (OE-IV)	3	0	0	6	3	OE
5.		Open Elective -V (OE-V)	3	0	0	6	3	OE
6.	EE4091E	Summer Internship	0	0	0	6	2	PC
7.	EE4092E	Project	0	0	0	9	3	PC
		Total (Excluding the Minor Courses)	**15**	**0**	**0**	**45**	**20**	

Semester VIII

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	EE4093E	Project	0	0	0	18	6	PE
		OR						
1.	EE4094E	Internship	0	0	0	**18**	6	PE
		OR						
1.1	EE40XXE	Programme Elective-II (PE-II)	3	0	0	6	3	PE
1.2	EE40XXE	Programme Elective-III (PE-III)	3	0	0	6	3	PE
		AND						
3		Open Elective -VI (OE-VI)	3	0	0	6	3	OE
4	EE4095E	Activity Credits	0	0	0	12	4	AC
		Total	**9/3**	**0**	**0**	**36/ 30**	**13**	

Total Credits: 153

Curriculum for B. Tech
in Electrical & Electronics Engineering with Minor in ……………..

PROGRAMME STRUCTURE

Semester I

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MA1001E	Mathematics I	3	1	0	5	3	IC
2.	CE1011E	Engineering Graphics	2	0	2	5	3	IC
3.	EE1001E	Introduction to Electrical Engineering	3	1	0	5	3	PC
4.	EE1002E	Electrical Measurements	3	0	0	6	3	PC
5.	EE1003E	Electronic Circuits - I	3	1	0	5	3	PC
6.	EE1004E	Professional Ethics	1	0	0	2	1	IC
7.	EE1091E	Basic Electrical Engineering Lab	0	0	2	1	1	PC
		Total	**15**	**3**	**4**	**29**	**17**	**--**

Semester II

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MA1011E	Mathematics II	3	1	0	5	3	IC
2.	PH1003E	Electricity and Magnetism	3	0	0	6	3	IC
3.	MS1001E	Professional Communication	3	1	0	5	3	IC
4.	EE1011E	Circuits and Networks	3	1	0	5	3	PC
5.	ME1401E	Engineering Mechanics	3	0	0	6	3	PC
6.	EE1012E	Digital Circuits and Systems	3	1	0	5	3	PC
7.	EE1092E	Electrical Measurements Lab	0	0	2	1	1	PC
		Total	**18**	**4**	**2**	**33**	**19**	**--**

Semester III

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MA2001E	Mathematics III	3	1	0	5	3	IC
2.		Digital / Automation Technologies - I	3	0	0	6	3	IE
3.		E /I Elective	3	0	0	6	3	IE
4.	EE2001E	Signals and Systems	3	1	0	5	3	PC
5.	EE2002E	Microprocessors and Microcontrollers	2	1	2	4	3	PC
6.	EE2003E	Electrical Machines -I	3	1	0	5	3	PC
7.	EE2004E	Electronic Circuits – II	3	1	0	5	3	PC
8.	EE2091E	Electronics Lab – I	0	0	2	1	1	PC
		Total	**20**	**5**	**4**	**37**	**22**	

Semester IV

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MA2011E	Mathematics IV	3	1	0	5	3	IC
2.	ME2011E	Mechanical Engineering	3	0	0	6	3	PC
3.	EE2011E	Power Systems - I	3	1	0	5	3	PC
4.	EE2012E	Power Electronics	3	1	0	5	3	PC
5.	EE2013E	Electrical Machines -II	3	1	0	5	3	PC
6.	EE2014E	Control Systems -I	3	1	0	5	3	PC
7.	EE2092E	Electrical Machines Lab – I	0	0	2	1	1	PC
8.	EE2093E	Electronics Lab – II	0	0	2	1	1	PC
9.		Minor Course-I	3/4	0	0	6/8	3/4	
Total (Including the Minor Courses)			**21/22**	**5**	**4**	**39/41**	**23/24**	

Semester V

Sl. No	Course Code	Course Title	L	T	P	O	Credits	Category
1.	EE3001E	Digital Signal Processing	3	1	0	5	3	PC
2.	EE3002E	Power Systems - II	3	1	0	5	3	PC
3.	EE3003E	Control Systems - II	3	1	0	5	3	PC
4.	EE3004E	Analog Integrated Circuits	3	0	0	6	3	PC
5.		Humanities - I	3	0	0	6	3	IE
6.		Digital / Automation Technologies - II	3	0	0	6	3	IE
7.	EE3091E	Power Electronics Lab	0	0	2	1	1	PC
8.	EE3092E	Electrical Machines Lab – II	0	0	2	1	1	PC
9.		Minor Course-II	3/4	0	0	6/8	3/4	
Total (Including the Minor Courses)			**21/22**	**3**	**4**	**41/43**	**23/24**	

Semester VI

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	EE3011E	Introduction to Communication Systems	3	0	0	6	3	PC
2.	EE3012E	Instrumentation Systems	2	1	2	4	3	PC
3.		Open Elective - I (OE-I)	3	0	0	6	3	OE
4.		Open Elective - II (OE-II)	3	0	0	6	3	OE
5.		Humanities - II	3	0	0	6	3	IE
6.	EE3093E	Electrical Engineering Drawing	1	0	2	3	2	PC
7.	EE3094E	Project	0	0	0	9	3	PC
8.	EE3095E	Power Systems Lab	0	0	2	1	1	PC
9.	EE3096E	Control Systems Lab	0	0	2	1	1	PC
10.		Minor Course-III	3/4	0	0	6/8	3/4	
Total (Including the Minor Courses)			**18/19**	**1**	**8**	**48/50**	**25/26**	

Semester VII

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.		Humanities -III	3	0	0	6	3	IE
2.	EE40XXE	Program Elective- I (PE-I)	3	0	0	6	3	PE
3.		Open Elective –III (OE-III)	3	0	0	6	3	OE
4.		Open Elective -IV (OE-IV)	3	0	0	6	3	OE
5.		Open Elective -V (OE-V)	3	0	0	6	3	OE
6.	EE4091E	Summer Internship	0	0	0	6	2	PC
7.	EE4092E	Project	0	0	0	9	3	PC
8.		Minor Course-IV	3/4	0	0	6/8	3/4	
		Total (Excluding the Minor Courses)	**18/19**	**0**	**0**	**51/53**	**23/24**	

Semester VIII

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	EE4093E	Project	0	0	0	18	6	PE
		OR						
1.	EE4094E	Internship	0	0	0	**18**	6	PE
		OR						
1.1	EE40XXE	Programme Elective-II (PE-II)	3	0	0	6	3	PE
1.2	EE40XXE	Programme Elective-III (PE-III)	3	0	0	6	3	PE
		AND						
3		Open Elective -VI (OE-VI)	3	0	0	6	3	OE
4	EE4095E	Activity Credits	0	0	0	12	4	AC
		Total	**9/3**	**0**	**0**	**36/30**	**13**	

Total Credits: 165-169

Minor Programme

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.		Minor Course-I	3/4	0	0	6/8	3/4
2.		Minor Course-II	3/4	0	0	6/8	3/4
3.		Minor Course -III	3/4	0	0	6/8	3/4
4.		Minor Course- IV	3/4	0	0	6/8	3/4
		Total	**12/16**	**0**	**0**	**24/32**	**12/16**

Syllabus

Semester-I

MA1001E MATHEMATICS I

Pre-requisites: NIL

L	T	P	O	C
3	1	0	5	3

Total Lecture sessions: 39

Course Outcomes:

CO1: Formulate some engineering problems as ODEs and hence solve such problems.
CO2 Solve linear ODEs with constant coefficients.
CO3: Find the limits, check for continuity and differentiability of real valued functions of two variables
CO4: Test for the convergence of sequences and series.
CO5: Find the Fourier series representing periodic functions.

Existence and uniqueness of solution of first order ODE, methods of solutions of first order ODE, linear ODE, orthogonal trajectories, linear homogeneous second order ODEs with constant coefficients, fundamental system of solutions, existence and uniqueness of solutions, Wronskian, method of undetermined coefficients, solution by variation of parameters, Euler-Cauchy equations, applications of first and second order ODEs, system of linear ODEs with constant coefficients.

Function of several variables: Limit, continuity, partial derivatives, partial differentiation of composite functions, directional derivatives, gradient, local maxima and local minima of functions of two variables, critical point, saddle point, Taylor's formula for two variables, hessian, second derivative test, method of Lagrange multipliers. Parameterised curves in space, arc length, tangent and normal vectors, curvature and torsion.

Sequences, Cauchy sequence, convergence of sequences, series, convergence of series, tests for convergence, absolute convergence, sequence of functions, power series, radius of convergence, Taylor series, periodic functions and Fourier series expansions, half-range expansions, Fourier integral, Fourier transforms and their properties.

References:

1. Anton, I. Bivens and S. Davis, *Calculus*, 10th edition, New York: John Wiley & Sons, 2015.
2. G. B. Thomas, M.D. Weirand J. Hass, *Thomas' Calculus*, 12th edition, New Delhi, India: Pearson Education, 2015.
3. E. Kreyszig, *Advanced Engineering Mathematics,* 10th edition, New York: John Wiley & Sons, 2015
4. Apostol, *Calculus* Vol 1, 1st ed. New Delhi: Wiley, 2014.

CE1011E ENGINEERING GRAPHICS

Pre-requisites: NIL

L	T	P/D	O	C
2	0	2	5	3

Total sessions: 26L + 26D

Course Outcomes:

CO1: Make use of the Indian Standard Code of Practice in Engineering Drawing
CO2: Represent any engineering object by its orthographic views
CO3: Convert orthographic views of an engineering object into its isometric view.
CO4: Use software for drawing and visualization of engineering objects

Introduction: Drawing instruments and their uses; lines, lettering and dimensioning; Introduction Auto CAD software, geometrical construction; constructions of plain and diagonal scales.
Orthographic projection—first and third angle projections (using CAD); orthographic projection of points on principal, profile, and auxiliary planes.
Orthographic projection of straight line in simple and oblique positions; application of orthographic projection of line

Orthographic projection of planes in simple and oblique position on principal and profile planes; orthographic projection of lines and planes on auxiliary planes. Orthographic projection of solids in simple and oblique positions on principal and profile planes; orthographic projections of solids in oblique position

Orthographic projection of solids in section; development of surfaces of solids; method of isometric projection (Using CAD). Introduction to perspective projection (no drawing)

References:

1. Agrawal B. and Agrawal C. M., *Engineering Drawing*, 3rd ed. McGraw Hill Education, 2019.
2. Bhatt, N. D., *Engineering Drawing*, 54th ed. Charotar Publishing House, 2023.
3. Venugopal K. and Raja V P, *Engineering Drawing + Auto CAD*, 6th Edition, New Age Intl. Pvt Ltd., 2022.

EE1001E INTRODUCTION TO ELECTRICAL ENGINEERING

Pre-requisites: NIL

L	T	P	O	C
3	1	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain the characteristics of voltage sources, current sources and various passive circuit elements.
CO2: Solve simple magnetic and capacitive circuits for signal and power processing.
CO3: Analyse electrical circuits using various circuit analysis methods and circuit theorems.
CO4: Analyse single phase ac circuits.
CO5: Analyse balanced and unbalanced three-phase ac circuits.

Study of Resistive Circuits
v-i relationship for Independent Voltage and Current Sources, Passive sign convention, Kirchhoff's Laws,
Solution of resistive circuits with independent sources- Node Voltage and Mesh Current Analysis, NodalConductance Matrix and Mesh Resistance Matrix and symmetry properties of these matrices

Circuits with Linear Dependent Sources: VCVS, VCCS, CCVS and CCCS - node analysis and mesh analysis of circuits containing resistors, independent sources and linear dependent sources - effect of dependent sources on the symmetry of nodal admittance matrix and mesh impedance matrix

Source Transformation and Star-Delta / Delta-Star Conversions to reduce resistive networks

Circuit Theorems and Energy Storage Elements
Circuit Theorems - Superposition Theorem, Thevenin's Theorem, Norton's Theorem, MaximumPower Transfer Theorem and Reciprocity Theorem. Determination of Thevenin's and Norton's equivalent for circuits containing dependent sources.

MMF, Magnetic Flux, Reluctance, Energy stored in a Magnetic Field, Solution of Magnetic Circuits.
Inductance - Faraday's Law of Electromagnetic Induction, Lenz's Law, Self and Mutual Inductance, Inductances in Series and Parallel, Mutual Flux and Leakage Flux, Coefficient of Coupling, Dot Convention, Cumulative and Differential Connection of Coupled Coils. Capacitance – Electrostatics, Capacitance, Parallel Plate Capacitor, Capacitors in series and parallel, Energy stored in Electrostatic Field
v-i relationship for Inductance and Capacitance

Analysis of Single-phase AC Circuits
Alternating Quantities - Average Value, Effective Value, Form and Peak factors for square, triangle,trapezoidal and sinusoidal waveforms. Power Superposition principle, Phasor representation of sinusoidal quantities - phase difference, Addition and subtraction of sinusoids,Symbolic Representation: Cartesian, Polar and Exponential forms.

Analysis of a.c circuits - R, RL, RC, RLC circuits using phasor concept, Concept of impedance,admittance, immittance, conductance and susceptance – Resonance in RLC circuits

Power in single phase circuits - instantaneous power, average power, active power, reactive power,apparent power, power factor, complex power, solution of series, parallel and series parallel a.c circuits. Thevenin's Theorem, Norton's Theorem and Maximum Power Transfer Theorem for a.c circuits.

Analysis of Three-phase AC Circuits
Polyphase circuit working - 3 phase a.c systems - balanced system - phase sequence - Star Delta Transformation Theorem - Balanced 3 phase a.c source supplying balanced 3 phase star connected and delta connected loads - 3 wire and 4 wire systems - Power in three phase balanced circuits: active power, reactive power, complex power, apparent power and power factor in balanced circuits.

Steady-state analysis of three-phase balanced loads excited by three-phase unbalanced sources, power factor in unbalanced three phase systems, neutral shift, neutral current, neutral tie, circulating currents- symmetrical transformation – sequence components – sequence decoupling – power in sequence components.

References:

1. K.S. Suresh Kumar, *Electric Circuits & Networks*, Pearson Education, 2009
2. J.W. NILsson and S.A. Riedel, *Electric Circuits*, 8th ed., Pearson, 2002
3. C. A. Desoer and E. S. Kuh, *Basic Circuit Theory*, McGraw Hill, 2009
4. J. A. Edminister, *Electric Circuit Theory*, Schaum's Outline series: 6th ed., McGraw Hill, 2014.

EE1002E ELECTRICAL MEASUREMENTS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total lecture sessions: 39

Course Outcomes:

CO1: Familiarization with different type of electrical measurement systems.
CO2: Analyze the working principles of resistance, inductance, capacitance and magnetic quantities with necessary skill development in instrument design.
CO3: Analyze the working principles of waveform measurements.
CO4: Perform measurement of power & energy in poly phase systems.

Voltage and current measurements
Concepts of measurement, static and dynamic characteristics of instruments, definitions relating to measuring instruments, errors in measurement principle, construction and working of moving coil instruments, principle, construction and working of moving iron instruments ,ammeter shunts, voltmeter multipliers, instrument transformers, current transformers-potential transformers, thermocouple instruments, electrostatic volt meter, rectifier voltmeters, Advantages and disadvantages of digital instruments, resolution, accuracy and error in digital measurements, digital multimeter.

Magnetic Measurements
Magnetic measurements, Ballistic galvanometer, calibration-flux meter, determination of BH curve and Hysterisis loop

Waveform Measurements
Cathode ray Oscilloscope, Electrostatic Deflection, Time Base Generator and Synchronization– Observation of Waveforms, Phase and Frequency (Lissajous Patterns) , Digital Storage Oscilloscope – sampling of waveforms for understanding the functioning of DSO (Basic understanding is expected).

Measurement of Resistance, Inductance and capacitances
Measurements of resistances, Ammeter–voltmeter method, Wheatstone bridge, Kelvin double bridge, measurement of high resistances, use of guard circuits, loss of charge method, Megger and insulation test, location of cable fault, Murray loop test, Varley loop test, Megger and insulation test, AC bridges, Maxwells Inductance bridge, Maxwells Inductance, Capacitance bridge, Hay's Bridge, Schering Bridge, Wein Bridge

Power and Energy measurements
Measurement of power in DC and AC circuits, Dynamometer type watt meters–Construction, Theory and operation, errors and calibration, power in poly phase systems, Blondel's theorem, measurement of power in three phase balanced and un balanced systems, measurement of reactive volt amperes, induction type single phase energy meters, Construction theory and operation-errors, compensation and adjustments-testing of energy meters, phantom loading, measurement of kVA.

References:

1. Golding E.W *Electrical Measurements & Measuring Instruments*, 6th ed. Reem Publications,2019.
2. Cooper W.D, *Modern Electronics Instrumentation*, PHI, 1996.
3. Stout M.B, *Basic Electrical Measurements*, Prentice Hall, 1986.
4. Oliver & Cage, *Electronic Measurements & Instrumentation*, McGraw Hill, 1979.
5. Sawhney A. K., *Electrical and Electronic Measurements and Instrumentation*, Dhanpat Rai &Co.,2015

EE1003E ELECTRONIC CIRCUITS - I

Pre-requisites: NIL

L	T	P	O	C
3	1	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Design Rectifiers with filters, Clipping Circuits, DC Restoration Circuits and simple voltage regulator circuits using diodes and zener diodes

CO2: Design biasing circuits as per specification for BJTs, JFETs and MOSFETs

CO3: Design single-stage and multi-stage amplification systems with specified mid-band performance using BJTs, JFETs and MOSFETs.

CO4: Design simple Class A, Class B and Class AB power stages using BJTs.

CO5: Conduct performance evaluation of prototype amplifier designs by small signal analysis procedure.

CO6: Choose digital components from various standard logic families in simple digital circuits with power supply current, propagation delay, rise and fall times etc., as basis of comparison.

Semiconductors Devices and Small Signal Models

Revision of principles of operation of diodes and bipolar junction transistors - transition capacitance of a diode - minority carrier storage-diffusion capacitance-breakdown diodes -schottky diode – forward and reverse recovery processes in a diode – Switching diode versus Rectifier diodes

Bipolar Junction Transistor capacitances- Emitter diffusion capacitance and its dependence on bias current, miller capacitance and its voltage dependence – Transistor ratings – Biasing a BJT – Various biasing schemes - Thermal stability of bias.

Concept of small signal operation of semiconductor devices – small signal equivalent circuit for diodes including capacitances – h-parameter equivalent circuit for a BJT – high-frequency hybrid-π equivalent for a BJT – determination of small signal parameters from static characteristics.

Construction and characteristics of JFETs – capacitances of a JFET – biasing a JFET - small signal model for a JFET

Construction and characteristics of depletion type and enhancement type MOSFETs – MOSFET capacitances – biasing a MOSFET – small signal model of a MOSFET including capacitances

Diode Circuits

Rectifier Circuits – Single-phase half-wave rectifier without filter capacitor, Single-phase half-wave rectifier with filter capacitor, Single-phase Full-wave rectifier with C-Filter, Single-phase Full-bridge rectifier with C- Filter, Full-wave and full-bridge rectifiers with LC Filter – Design of LC Filter – Rectifier ripple factor, transformer utilization factor etc., rectifier output voltage variation with loading.

Diode/Zener Diode Clipping Circuits and applications.

DC Restoration by Diode Clamping Circuits.

Voltage regulator design using Zener diodes.

BJT, JFET and MOSFET Amplifier Circuits – Midband Analysis

A Transistor as an amplifying element – Biasing for amplification – RC Coupling versus Direct Coupling - Signal coupling and signal bypassing - Graphical analysis and explanation for amplification in a CE amplifier - Midband gain, input resistance and output resistance of CE Amplifier , CB Amplifier and Emitter Follower - Analysis and Comparison using h parameters as well as hybrid-π parameters – Qualitative explanation for low-frequency and high-frequency response of amplifiers - considerations in cascading transistor amplifiers – Common Source and Common Drain Amplifiers using JFETs and MOSFETs – comparison of BJT, FET and MOSFET amplifiers – Class A, Class B and Class AB Power Amplifiers using BJT.

Digital Logic Families

Transistor as an inverter (i.e., resistive switching) – switching delays – various components of switch-off and switch-on delays – calculation of switching time components – comparison between high frequency transistor and switching transistor.

Charging and discharging a capacitive load by a BJT and MOSFET – rise time and fall time calculations for capacitive load switching in both cases
Analysis of basic DTL gate, propagation delay, rise and fall times, fan-in and fan out – power supply current versus frequency of operation
Analysis of basic TTL gate, propagation delay, rise and fall times, fan-in and fan out, ratings, power supply current versus frequency of operation
Different variants of TTL gates including Schottky TTL
Analysis of basic ECL gate, propagation delay, rise and fall times, fan-in and fan out.
Analysis of basic CMOS gate, propagation delay, rise and fall times, fan-in and fan out – power dissipation in the gate and effect of (i) supply voltage (ii) frequency of operation and (iii) load capacitance on gate dissipation – Different variants of CMOS Logic Families
Comparison of various digital logic families – speed-power product as a figure of merit.

References:

1. A.S Sedra and K.C Smith, *Microelectronic Circuits*, 5th ed. Oxford University Press, 2009
2. Taub & Scilling, *Digital Integrated Electronics*, McGraw-Hill, Singapore, 1997
3. Millman J, *Microelectronic*, 2nd ed. McGraw-Hill, New Delhi, 2005.
4. Schilling & Belove, '*Electronic Circuits – Discrete and Integrated*, 3rd ed. McGraw-Hill, New Delhi, 2006
5. Boylested & Nashesky, *Electronic Devices and Circuit Theory*, 10th ed. Pearson Education, New Delhi, 2009

EE1004E PROFESSIONAL ETHICS

Pre-requisites: NIL

L	T	P	O	C
1	0	0	2	1

Total Lecture Sessions: 13

Course Outcomes:

CO1: Develop a clear understanding of human values and use it as basis for all the activities.
CO2: Understand and follow the ethical aspects of engineering profession.
CO3: Align with the Code of Ethics prescribed by IEEE in all professional activities.
CO4: Assimilate the elements of academic integrity and Honour Codes, and adopt them in all relevant activities.

Human Values
Morals, values and ethics – integrity – work ethic – service learning – civic virtue – sharing – honesty – courage – valuing time – cooperation – commitment – empathy – self-confidence – character.

Ethics in Professional Practice
Ethics in professional context – ethical basis of engineering activities – ethical responsibilities to consumers and customers – safety and risk – ethics in management of intellectual property – environmental matters and sustainability.

Code of Ethics and Academic Integrity
An overview about IEEE code of ethics - Integrity, responsible behavior, ethical conduct- treating others fairly and respectfully, avoid harassment, discrimination and injuries to others – helping others to keep ethics in their life

Elements of Academic Integrity: honesty, trust, fairness, respect, responsibility – plagiarism as a violation of academic integrity – Honour Codes: specifying the expected ethical standards from the stakeholders of an organization.

References:

1. R.S. Naagarazan, A Textbook on Professional Ethics and Human Values, 3rd edn., 2022, New Age International Pvt. Ltd.
2. A.F. Bainbridge, Ethics for Engineers: A Brief Introduction, 2021, CRC Press
3. E.G. Seebauer and R.L. Barry, Fundamentals of Ethics for Scientists and Engineers
4. IEEE Code of Ethics – available at ‘https://www.ieee.org/about/corporate/governance/p7-8.html’ (accessed on 2nd June 2023)
5. International Center for Academic Integrity – available at ‘https://academicintegrity.org/’ (accessed on 2nd June 2023)

EE1091E BASIC ELECTRICAL ENGINEERING LAB

Pre-requisites: NIL

L	T	P	O	C
0	0	2	1	1

Total Practical Sessions: 26

Course Outcomes:

CO1: Perform basic electrical wiring, select fuse for a given electrical circuit and perform electrical measurements using different meters and instruments
CO2: Estimate and measure power, power factor and current of linear and non-linear types of loads.
CO3: Apply basic circuit theorems to electrical circuits and design potential divider circuits for given specifications.
CO4: Measure winding inductance and analyse the resonance phenomena in RLC circuits
CO5: Measure earth resistance and insulation resistance
CO5: Prepare laboratory reports that clearly communicate experimental information in a logical and scientific manner.

Syllabus / List of Experiments:

1. a) Familiarization of wiring tools, lighting and wiring accessories, various types of wiring systems.
   b) Wiring of one lamp controlled by one switch.
2. a) Study of Electric shock phenomenon, precautions, preventions, Earthing.
   b) Wiring of one lamp controlled by two SPDT Switches and one 3 pin plug socket independently.
3. a) Study of Fuse, MCB, ELCB – Selection of Fuse rating for circuits.
   b) Wiring of fluorescent lamp controlled by one switch with ELCB & MCB.
4. a) Study of Analog/Digital meters/Multimeters/DSOs.
   b) Characteristics of Linear and Non- linear loads – Determination of voltage – current characteristics of linear resistor and linear inductor, incandescent and CFL/LED lamps, iron cored solenoid
5. Verification of Kirchhoff's laws in D.C circuits.
6. a) Potential divider connection and study of the dependence of output voltage upon the value of theloading resistance.
   b) Methods of measurement for low- medium-high resistance using voltmeter and ammeter.
7. Verification of Superposition Theorem and Maximum Power Transfer theorem.
8. Verification of Thevenin's Theorem and Generalized Reciprocity theorem.
9. a) Single phase power measurement (fan load) – study of variation of speed, input power and powerfactor with supply voltage.
   b) Determination of thermal efficiency of an electric kettle.
10. Experiments and Analysis of Resonance in the RLC circuits.
11. Measurement of Self-inductance, Mutual inductance and Coupling coefficient of windings.
12. Measurement of Earth Resistance and Insulation Resistance.

Note: Normally the practical classes are administered in two cycles. Depending on the availability of equipment and time, class coordinators may choose the experiments for each cycle.

References:

1. H Cotton, *Advanced Electrical Technology*, Reem Publications, 2011.
2. Suresh Kumar K.S, *Electrical Circuit and Networks*, Pearson Education, New Delhi, 2009.
3. EW. Golding, *Electrical Measurements and Measuring Instruments*, 5th ed. Reem Publications, 2011.

Semester-II

MA1011E MATHEMATICS II

Pre-requisites: NIL

L	T	P	O	C
3	1	0	5	3

Total Lecture Sessions: 39

Course Outcomes

CO1: Find the parametric representation of curves and surfaces in space and evaluate integrals over curves and surfaces

CO2: Use Laplace transform and its properties to solve differential equations and integral equations.

CO3: Test the consistency of the system of linear equations and solve it.

CO4 Diagonalise symmetric matrices and use it to find the nature of quadratic forms.

Vector field, divergence, curl, identities involving divergence and curl, scalar potential, line integral, independence of path, conservative field, evaluation of double integral, change of variables, Jacobian, polar coordinates, Green's theorem for plane, finding areas using Green's theorem, triple integral, cylindrical and spherical coordinates, mass of a lamina, centre of gravity, moments of inertia, parameterized surface, surface area and surface integral, flux, Gauss' divergence theorem, Stokes' theorem.

Laplace transform, sufficient condition for existence, linearity, inverse Laplace transform, Dirac delta function, transforms of derivatives and integrals, shifting theorems, convolution, differentiation and integration of transform, solution of differential equations and integral equations using Laplace transform.

System of linear equations, augmented matrix, existence and uniqueness of solution, Gauss elimination method, elementary row operations, LU decomposition, row-equivalent systems, row echelon form, rank of a matrix, linear dependence, consistency of linear system, linear combination of solutions, general solution. types of matrices and their properties, eigenvalues, eigenvectors, eigenvalue problems, Cayley- Hamilton theorem, similarity of matrices, diagonalisation, quadratic form, reduction to canonical form.

Vector field, divergence, curl, identities involving divergence and curl, scalar potential, line integral, independence of path, conservative field, evaluation of double integral, change of variables, Jacobian, polar coordinates, Green's theorem for plane, finding areas using Green's theorem, triple integral, cylindrical and spherical coordinates, mass of a lamina, centre of gravity, moments of inertia, parameterized surface, surface area and surface integral, flux, Gauss' divergence theorem, Stokes' theorem.

References:

1. E. Kreyszig, *Advanced Engineering Mathematics*, 10^{th} edition, New Delhi, India: Wiley, 2015.
2. H. Anton, I. Bivens and S. Davis, *Calculus*, 10^{th} edition, New York: John Wiley & Sons, 2015.
3. V. I. Arnold, *Ordinary Differential Equations*, New York: Springer, 2006.
4. P. Dyke, *An Introduction to Laplace Transforms and Fourier Series*, New York: Springer,2014.

PH1003E ELECTRICITY AND MAGNETISM

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Apply knowledge of vector calculus to describe Electric and Magnetic fields.
CO2: Identify simplifying principles like symmetry to compute Electric and Magnetic fields.
CO3: Formulate and solve problems involving time dependent electromagnetic fields using Maxwell's equations.
CO4: Analyse propagation of electromagnetic waves in vacuum and dielectric media.

Electrostatics
Electric field – charge density: line, surface and volume – Coulomb's law – Coordinate systems and vector fields: rectangular, cylindrical and spherical coordinates, divergence and curl of Electric field – Gauss law – potential – gradient of the potential – Poisson and Laplace equation – electrostatic work and energy – conductors and electric fields – field and potential of dipoles – electric polarization vector – Gauss law for a dielectric medium – electrostatic boundary conditions.

Magnetostatics
Electric current – current density – surface and volume currents – continuity equation – magnetic field – Biot-Savart law – divergence and curl of magnetic field – Ampere's law – field due to a magnetic dipole – magnetic dipole in external magnetic field – magnetostatic energy – magnetized materials – magnetostatic boundary conditions

Time varying Fields
Electromotive force – Faraday's law – Lenz law – electromagnetic induction – mutual and self- inductance – Maxwell's equations – Maxwell's correction to Ampere's law – displacement current – electromagnetic field – energy density – Poynting's theorem

Electromagnetic Waves
Maxwell's equations in free space – wave equation – plane wave solution – structure of the electromagnetic wave – spherical waves – propagation in dielectric medium and refractive index

References:

1. D. J. Griffiths, *Introduction to Electrodynamics (4th Edition)*, PHI Learning, New Delhi, 2015.
2. E. Purcell and D. Morin, *Electricity and Magnetism (3rd Edition)*, Cambridge University Press, 2013.
3. M. O. Sadiku and S. V. Kulkarni, *Principles of Electromagnetics (6th Edition)*, Oxford University Press, 2015.
4. D. J. Cheng, *Field and Wave Electromagnetics (2nd Edition)*, Pearson, 2014.
5. R. P. Feynman, R. Leighton and M. Sands, *Feynman Lectures on Physics Vol.-II (Millennium Edition)*, Pearson, 2012.
6. J. Edminister, *Schaum's Outline: Theory and Problems in Electromagnetics (revised 2nd Edition)*, Tata McGraw-Hill, 2010.

MS1001E PROFESSIONAL COMMUNICATION

Pre-requisites: NIL

L	T	P	O	C
3	1	0	5	3

Total Lecture Sessions : 39

Course Outcomes:

CO1: Distinguish the role and purpose of communication at the workplace and for academic purposes.
CO2: Decide strategies and modes for effective communication in a dynamic workplace.
CO3: Combine multiple approaches for successful and ethical information exchange.
CO4: Estimate best communication practices to assist productivity and congeniality at the workplace.

Listening and Reading Comprehension
Conversation starters: introductions and small talk - Seek and provide information, clarification, polite enquiries, requests, congratulate people, apologise, give and respond to feedback - Describe graphs, tables, and charts - Words often confused: Lexicon and Meaning - Sense Groups - Listening for specific purposes: Listening to lectures, Summarise academic lectures for note-taking - Appropriate Language to Request and Respond - Public Speaking

Vocabulary and Speaking
Developing professional vocabulary - Basic Sentence Structures from Reading Texts - Concord - Functions of Auxiliary Verbs and Modals - Strategies for Effective Reading - Skimming and Scanning, Determine themes and main ideas, Predicting content using photos, images and titles - Critical Reading: Discussing and Summarising text points - Understanding Text Structures: sequencing, comparing and contrasting, relating cause and effect, problems and problem-solving - Discussing Rhetorical and Cultural Aspects in Texts - Text Appreciation: Drawing inferences, Framing Opinions and Judgments on Reading Text

Effective Writing
Note Making and Summarising: Prepare notes from reading texts, Paraphrasing - Use of Multimedia for Assistive Purposes - Paragraph Writing: cohesive devices to connect sentences in a paragraph - transitional devices - Use Text Structures in Paragraphs: sequencing, comparing and contrasting, relating cause and effect, problems and problem-solving - Avoiding Ambiguity and Cleft Sentences - Applications- Writing Instructions, Descriptions and Explanations - Official Letters of Request and Denial - Official E-mails - Abstract Writing - Digital Resources for Effective Communication

Communication at Workplace
Communication Theory - Process of Communication - Modes of Communication - Verbal and Non-Verbal Communication - Tone in Communication - Formal and Informal Communication at Workplace - Passive, Assertive and Aggressive Styles of Communication - Positive Body Language - Group Discussions - Presentation - Workplace Communication - Active Listening - Giving Feedback - Communication Etiquette - Persuasion - Negotiation - Tone and Voice - Telephone etiquette - Establishing Credibility in Conversations - Digital Communication and Netiquette: Conducting Oneself in Virtual Interactions, Constructive use of Social media - Ethical and Culturally Sensitive Communication: Ethical considerations in professional communication, Addressing diversity, Inclusive Communication Practices

References:

1. Bhatnagar N and Bhatnagar, M, *Communicative English for engineers and professionals*. Dorling Kindersley, 2010.
2. Foley, M and Hall, D, *Longman advanced learners 'grammar: A self-study reference & practice book with answers*. Pearson Education, 2018.
3. Garner, B. A., *HBR Guide to better business writing: Engage readers, tighten and Brighten, make your case*. Harvard Business Review Press, 2012.
4. Hewings, M, *Advanced grammar in use: A reference and practice book for Advanced learners of English*. Cambridge University Press, 2013.

5. Ibbotson, M, *Cambridge English for engineering*. Cambridge University Press, 2015.
6. Kumar, S., and Lata, P, *Communication skills*. Oxford University Press, 2015.
7. Sudarshana, N., and Savitha, C, *English for Technical Communication*. Cambridge English, 2016.

EE1011E CIRCUITS AND NETWORKS

Pre-requisites: NIL

L	T	P	O	C
3	1	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyse dynamic and steady state response of electrical circuits in time domain

CO2: Analyse dynamic and steady state response of electrical circuits in frequency domain

CO3: Examine simple first-order and second-order electrical circuits to perform basic signal processing tasks employing frequency response approach

CO4: Solve two-port systems by applying two-port network modelling.

Circuit Analysis in Time-domain

Time Domain Analysis of Circuits**:** Time domain analysis of simple series and parallel RL, RC, RLC circuits by differential equation method - Determination of initial conditions and its interpretation – Interpretation of various response components- Time constant and its interpretation-Steady-state response versus forced response and various kinds of steady-state response. Zero-input response, zero-state response and their interpretation- Obtaining step response and ramp response of circuits from impulse response

Solution of multi-mesh and multi-node circuits (containing RLCM and linear dependent sources) by differential equation method - Determination of initial conditions- the important properties exhibited by nth order linear time-invariant circuits

Circuit Analysis in Frequency-domain

Review of Laplace Transforms: Transform Pairs-Gate Functions-Shifting Theorem -Solution of Differential Equations by Laplace Transforms - Initial and Final Value Theorems – Laplace Transforms of periodic signals- Inversion of transforms by partial fractions

s-domain Analysis of Circuits - Transformed equivalent of inductance, capacitance and mutual inductance -Impedance and admittance in the transform domain – concept of the transformed circuit in *s*-domain –

Node Analysis and Mesh Analysis of the transformed circuit - Nodal Admittance Matrix and Mesh Impedance-Matrix in the s-domain-Solution of transformed circuits with mutual inductance – step response of an ideal transformer – step response of a non-ideal transformer– instantaneous change in current in coupled coil systems.

Generalization of Circuit theorems – Input and transfer immittance functions - Transfer functions - Impulseresponse and Transfer function - Poles and Zeros - Pole Zero plots – Stability and poles

Sinusoidal Steady - State Frequency Response and Fourier Analysis

Sinusoidal steady - state and frequency response function – frequency response function as a complex function of ω as evaluated from phasor equivalent circuit - frequency response function from s-domain transfer and immittance functions- explanation for substituting $s=j\omega$ in transfer function to obtain frequency response function – Properties of frequency response function of LTI circuits.

Frequency response of first order circuits – concept of cut-off frequencies and bandwidth – Series and parallel RC circuits as an averaging filter (for current signal and voltage signal), low-pass filter, high-pass filter, integrator, differentiator, signal coupling circuit, signal bypassing circuit etc.

Series and Parallel RLC circuit frequency response - Graphical evaluation of frequency response function from pole-zero plots: introduction to filtering and illustration of graphical evaluation of frequency response function from pole-zero plots in the case of standard second order filter functions using Series RLC and Parallel RLC Circuits – frequency response specifications for second order functions – correlation between time-domain specs and freq-domain specsin the case of first order and second order circuits.

Review of Fourier Series representation of non-sinusoidal periodic waveforms: Fourier Coefficients-Determination of Coefficients-Waveform Symmetry-Exponential Fourier Series - Discrete Amplitude and Phase Spectra

Steady State Solution of Circuits with non-sinusoidal periodic inputs: by Fourier Series and frequency response function, power and rms value of non-sinusoidal waveforms, Discrete Power Spectrum, THD measure for waveforms.

Two Port Networks

Two Port Networks**:** Two port networks-characterization in terms of impedance, admittance, hybrid and transmission parameters - inter relationships among parameter sets - Interconnectionof Two port networks: Series, Parallel and Cascade - Input impedance, output impedance and gain of terminated two-ports in terms of two-port parameters and termination impedance – Applications of two-port parameters in negative feedback systems, power transmission

Dependent source equivalent circuits for coupled coils – ac steady-state analysis of circuits containing coupled coils – the perfectly coupled two-winding transformer and the ideal two-winding transformer.

References:

1. K. S. Suresh Kumar, *Electric Circuits and Networks*, Pearson Education, New Delhi, 2009.
2. M. E. Van Valkenburg, *Network Analysis*, Revised 3rd ed. Pearson Education, 2019.
3. W. H. Hayt, J. E. Kemmerly, *Engineering Circuit Analysis*, 9th ed. McGraw- Hill, 2020.
4. John D. Ryder, *Networks, Lines and Field*s, 2nd ed. Pearson, 2015.

ME1401E ENGINEERING MECHANICS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Determine the resultants of a force system.
CO2: Solve rigid body statics problems using equations of equilibrium.
CO3: Determine the first and second moments of area for planar surfaces.
CO4: Perform kinematic analysis of particles.
CO5: Solve particle dynamics problems using Newton's laws, energy methods and momentum methods

Equivalent force systems
Introduction: idealizations of mechanics, vector and scalar quantities, equality and equivalence of vectors, laws of mechanics, elements of vector algebra – Important vector quantities: position vector, moment of a force about a point, moment of a force about an axis – couple and couple moment: definition, couple moment as a free vector, moment of a couple about a line – Equivalent force systems: translation of a force to a parallel position, resultant of a force system, simplest resultant of special force systems – distributed force systems.

Rigid body statics
Equations of equilibrium: free-body diagram, free bodies involving interior sections, general equations of equilibrium – problems of equilibrium – static indeterminacy – Friction forces: laws of Coulomb friction, simple contact friction problems.

Properties of surfaces
First moment and centroid of plane area – second moments and product of area for a plane area: transfer theorems, rotation of axes, polar moment of area, principal axes.

Particle kinematics
Introduction – differentiation of a vector with respect to time – velocity and acceleration calculations in rectangular coordinates – velocity and acceleration in terms of path variables and cylindrical coordinates – simple kinematical relations and applications.

Particle dynamics
Newton’s law for rectangular coordinates – rectilinear translation – Newton’s law for cylindrical coordinates – Newton’s law for path variables – general motion of a system of particles – energy methods: introduction, conservative force field, conservation of mechanical energy, alternative form of work-energy equation – energy methods for a system of particles – methods of momentum for particles – Linear impulse and momentum relations for a single particle and system of particles – moment-of-momentum equation for a single particle and system of particles.

References:

1. I. H. Shames and G. K. M. Rao, *Engineering Mechanics – Statics and Dynamics*, 4th ed. Pearson Education India, 2005.
2. F. P. Beer, E. R. Johnston Jr., P. J. Cornwell, B. P. Self, D. F. Mazurek, and S. Sanghi, *Vector Mechanics for Engineers – Statics and Dynamics.* 12th ed. McGraw Hill, 2019.
3. J. L. Meriam, L. G. Kraige, and J. N. Bolton, *Engineering Mechanics – Statics and Dynamics*, 9th ed. Wiley, 2021.
4. R. C. Hibbeler, *Engineering Mechanics – Statics and Dynamics*, 14th ed. Pearson, 2017.

EE1012E DIGITAL CIRCUITS AND SYSTEMS

Pre-requisites: NIL

L	T	P	O	C
3	1	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Formulate Combinational Logic Problems and perform Logic Optimization

CO2: Design combinational logic applications using standard SSI and MSI gates and state of the art MUX, ROM, PLA and PAL units

CO3: Perform design verification/validation of synchronous and asynchronous sequential circuit designs.

CO4: Design synchronous and asynchronous sequential circuits for simple applications

Combinational Logic Design

Boolean functions: - canonical and standard forms - simplification of Boolean functions by Karnaugh map up to five variable map - NAND, NOR, EX-OR & EX-NOR implementation - multi level NAND circuits – multilevel NOR circuits

Binary Number Operations: Binary representations, Binary Arithmetic, Binary codes, Octal and Hexadecimal codes

MSI and LSI Combinational circuits and their applications: Arithmetic Circuits, Comparators and parity generators, multiplexers and demultiplexers, decoders and encoders, 7-segment display drivers - AND-OR-INVERT gates, Wired-OR logic, Tri-State Bus systems

Combinational circuit design using Multiplexer

Practical aspects: Fan-in and Fan-out, propagation delay, timing diagrams, glitches, power supply decoupling, power supply current requirements.

Introduction to Sequential circuits

Need for sequential circuits, basic architectural difference between combinational and sequential logic, concept of memory, the binary cell, switch debouncing using binary cell,

Asynchronous versus synchronous sequential machines, basics of sequential machine operation, classification of sequential machines

Latches and flip-flops (RS, JK, D, T and Master Slave) - Design of a clocked flip-flop – Flip-flop conversion – clocks and oscillators.

Practical clocking aspects concerning flip-flops – timing and triggering considerations – clock skew - Shift registers – parallel & serial, serial transfer – universal shift register- study of IC-74LS95 and IC74LS195

Counters: - Binary Ripple Counter, Binary Synchronous UP/DOWN Counter, Binary Counter with Parallel Load, BCD Counters, Modulo-n counters, Ring Counter, Johnson Counter – cascading of counters – study of ICs 74LS90, 74LS93, 74192, 74193 - Sequence detector/Recogniser.

Analysis and Design of Sequential Circuits

General model of sequential networks - State diagrams – Analysis and design of Synchronous sequential Finite State Machine – Exact State reduction – State reduction with don't cares -Minimization and design of the next state decoder.

Design of counters with arbitrary count sequence and unused states, design of sequence detectors.

Asynchronous sequential logic: Analysis and Design – Race conditions and Cycles – Hazards in combinational circuits – Hazard-free realization.

Practical design aspects: Timing and triggering considerations in the design of synchronous circuits – Setup time - Hold time – Clock skew - Static timing analysis - Dynamic analysis - Debugging and testing of Sequential circuit design.

Memory and Programmable Logic

Random Access Memory, Memory decoding, Error detection and correction, Read-Only Memory, ROMs PROMs and applications, PLA, PAL -Combinational circuit implementation using ROM, PAL and PLA – FPGAs - Introduction to Sequential Programmable Devices - Introduction to circuit simulators (SPICE) and hardware description languages (HDL) such as VHDL.

Practical design aspects: Sequential circuit implementation using ROMs.

References:

1. M. M. Mano and M. D. Ciletti, *Digital Design*, 6th ed. Pearson, 2018.
2. C. E. Strangio, *Digital Electronics: Fundamental Concepts and Applications*, PHI, 1987.
3. C. H. Roth, *Fundamentals of Logic Design*, 7th ed. Jaico Publishers, 2013.
4. W. I. Fletcher, *An Engineering Approach to Digital Design*, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1980.
5. R. J. Tocci, and N. S. Widmer, *Digital Systems - Principles and Applications*, 11th ed. Prentice Hall, 2010.
6. J. F. Wakerly, *Digital Design: Principles and Practices*, 4thed. Prentice-Hall, 2008.
7. D.D. Givone, *Digital Principles and Design*, Tata McGraw-Hill, 2003
8. R. Katz, *Contemporary Logic Design*, 2nd ed. Addison Wesley, 2004.
9. D. Lewin and D. Protheroe, *Design of Logic Systems*, 2nd ed. Chapman & Hall, University and Professional Division, 1992.
10. T. L. Floyd, *Digital Fundamentals*, 11th ed. Prentice Hall, 2017.

EE1092E ELECTRICAL MEASUREMENTS LAB

Pre-requisites: NIL

L	T	P	O	C
0	0	2	1	1

Total Practical Sessions: 26

Course Outcomes:

CO1: Use different electrical calibration and measurement devices.
CO2: Determine loss characteristics of a magnetic material.
CO3: Design measuring devices employing range extension principles.
CO4: Measure characteristics of electrical elements employing DC and AC Bridge technique.
CO5: Prepare laboratory reports that clearly communicate experimental information in a logical and scientific manner.

Syllabus / List of Experiments:

1. Extension of range of ammeter/voltmeter using shunt/series resistance and calibration of the meter using standard ammeter/voltmeter.
2. Measurement of low/medium resistance using Kelvin's double bridge and Wheatstone's bridge.
3. Measurement of inductance and capacitances using AC Bridges and LCR meter
4. Extension of range of a dynamometer type wattmeter using CT/PT and calibration of the extended meter using a standard wattmeter.
5. Calibration of single – phase energy meter by direct loading and phantom loading at various powerfactors.
6. Measurement of three phase power using two wattmeter method.
7. Measurement of reactive power and power factor with different loads.
8. Calibration of 3-phase energy meter using standard wattmeter.
9. Determination of Iron losses using Lloyd Fischer square
10. Determination of hysteresis loop of an iron ring specimen using DSO/CRO.
11. Determination of ratio error and phase error of CT.

Note: Normally the practical classes are administered in two cycles. Depending on the availability of equipment and time, class coordinators may choose the experiments for each cycle.

References:

1. Golding E.W, *Electrical Measurements & Measuring Instruments*, 5th ed. Reem publications, 2009.
2. Cotton.H, *Advanced Electrical Technology*, Wheeler Publications, 2011.
3. Suresh Kumar K.S *Electric Circuit and Networks,* Pearson education, 2009.
4. Cooper W.D, *Modern Electronics Instrumentation*, Prentice Hall of India, 1986.

EE2001E SIGNALS AND SYSTEMS

Pre-requisites: NIL

L	T	P	O	C
3	1	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Design and validate simple first order and second order linear continuous-time systems in various domains by analytical as well as experimental methods.

CO2: Evaluate multi-order LTI System designs by Impulse Response Test

CO3: Evaluate stability and stability margins of a proposed CT-LTI design by transfer function approach.

CO4: Design simple first-order and second-order systems for basic signal/energy processing applications from given transfer function/ impulse response/ steady-state requirements in electrical and thermal domains.

CO5: Evaluate the signal distortion characteristics of a given transmission channel.

First Order CT- LTI Systems in Time-domain

Signals and Systems - System as interconnection of elements – electrical system elements, thermal system elements, translational and rotational mechanical system elements.

Signal definition – Size of a signal - Classification of signals – Basic signal operations – Commonly used signal models (impulse, step, ramp, complex exponential etc), even and odd components of a signal.

Linearity of system elements – element relation – superposition principle – Time-invariance - Bilateral versus unilateral elements

Independent source elements – voltage, current, force, velocity, heat, temperature sources - Interconnection of elements – interconnection laws for electrical, mechanical and thermal systems

Formulation of System Differential Equation - Formulation of differential equation for Series and Parallel RC circuits, Series and Parallel RL circuits, mass-damper system, single body heating and cooling system – need for initial condition specification - equivalence between impulse excitation and initial conditions

First-Order Dynamics- Source-free response of RC circuit – time constant – Source-free response of RL circuit – time constant –Source-free response of first order mechanical system and thermal system – mechanical time constant, thermal time constant – DC switching problem in RC and RL Circuits with and without initial energy storage– Natural response and forced response – transient response – Rise time and fall time in first order systems – Difference between DC switching and applying step input - Complete Solution for step/impulse/sinusoid inputs – First order mechanical system impulse and step response - First order thermal system impulse and step response, generalisations for all first order systems (Eg. Mechanical systems, Thermal Systems etc.)– zero-input response and zero-state response – relation between them to natural response and transient response – superposition principle as applied to various response components.

Concept of steady-state – DC steady-state in RC and RL Circuits – Sinusoidal steady-state in first order systems - sinusoidal steady-state frequency response function of first order systems – periodic steady-state in first order systems.

Higher Order CT - LTI Systems in Time-domain – Impulse Response Description

Time-domain analysis of second-order systems – The mass-spring-damper system (for example, an ammeter or voltmeter) - series and parallel RLC – initial conditions – zero-state and zero-input response components - impulse response – step response – undamped and damped natural frequencies – damping factor – quality factor – undamped spring-mass system and LC system – weakly damped spring-mass system and LC system – Q factor versus rate of decay in stored energy in a weakly damped system - time-domain specifications for a second order system.

Time-domain analysis of higher order systems – Formulation of differential equation for multi-mesh circuits – determination of initial conditions - solution of nth order Linear ODE using material learnt from Maths Courses - natural frequencies – natural frequencies versus stability – frequency response function in terms of coefficients of differential equation - generalisations for nth order linear time-invariant system - Instability in circuits involving dependent sources.

Convolution Integral – Impulse decomposition of an arbitrary input– convolution integral for zero-state response of a LTI system – importance of impulse response – scanning function – depth of memory of an LTI system and duration

of impulse response – relation between DC steady-state output and impulse response – relation between AC steady-state frequency response function and impulse response.
Properties of systems – linearity, time-invariance, causality and stability in terms of impulse response – cascading LTI systems with and without inter-stage interaction.
Zero-state output of an LTI System for complex exponential input – condition of 'dominance' - eigen function – eigen value versus system function – system function H(s) of a nth order LTI system

CT- LTI Systems in Frequency-domain - with Arbitrary Inputs
[Revise Fourier Series and analysis of LTI Systems for periodic inputs using Fourier Series and Frequency Response Function – No class time allotted.]
Signal Expansion in terms of e^{-st} kind of signals – Fourier Transforms (FT)
Aperiodic inputs – Fourier Transform from Fourier Series – interpretation of Fourier transform – revise what was learnt in Maths I (properties and theorems)– frequency response function and its role in LTI system solution for aperiodic inputs – band-limiting versus time-limiting of signals – continuity of Fourier transform – convolution theorem – modulation theorem.
Linear distortion in signal transmission context – amplitude and phase distortion – conditions for distortion-free transmission – why such conditions cannot be met in practice – Practical distortion criterion for pulse transmission in terms of energy content of output.
Sampling of CT signals and reconstruction – Nyquist's Theorem on sampling – ideal interpolation versus practical interpolation.
Signal Expansion in terms of e^{-st} kind of signals – Laplace Transforms (LT)
Laplace transform from Fourier transform – LT as signal expansion in terms of complex exponential functions – ROC – revise what was learnt in Maths – Unilateral Laplace Transform – Shifting theorem - use of LT for solving complete response of LTI system – transfer function and its relation with what was called system function earlier – poles, zeros-impulse response from pole-zero plot – relation between transfer function and frequency response

References:

1. Lathi, B.P., *Signal Processing and Linear Systems*, 2nd ed., Oxford University Press, New Delhi, 2006
2. Lathi, B.P., *Signals, Systems and Communication*, BS Publications, Hyderabad, 2008
3. K.S. Suresh Kumar, *Electric Circuits and Networks*, Pearson Education, New Delhi, 2009
4. Alan V Oppenheim, Ronald W. Schafer, *Discrete-Time Signal Processing*, 3rd ed., Pearson Education India Pvt. Ltd., 2014.
5. Charles L. Phillips, John M. Parr & Eve A. Riskin, *Signals, Systems and Transforms*, 5th ed., Pearson Education, 2013
6. Simon Haykin, Barry Van Veen, *Signals and Systems*, 2nd ed., Wiley India, 2009

EE2002E MICROPROCESSORS AND MICROCONTROLLERS

Pre-requisites: NIL

L	T	P	O	C
2	1	2	4	3

Total Sessions: 26 (L) + 13(T) + 26(P)

Course Outcomes:

CO1: Explain the basics of Digital Systems.
CO2: Discuss the working of a microprocessor/controller.
CO3: Develop and test programs for processors using assembly / high-level language.
CO4: Test the working of different peripherals in a digital system.
CO5: Design, modify, compile, and debug an assembly / C-Program and generate an executable file for PIC microcontroller from the code.

Basics of computer
Number systems – Computer languages of different levels – compilers – cross compilers- History of Microprocessors – Computer architecture (Block diagram) – Memory types, Addressing concept, Timing diagrams. Memory organization –CISC Vs RISC design philosophy, Von-Neumann Vs Harvard architecture

Experiment:

1. Convert from given number (Including floating point numbers) from any number system to any other (among 1.Decimel, 2.Hexadecimal, 3.Binary and 4.Octal systems).

Microcontrollers
Microchip PIC 18F 452 Microcontroller - Introduction - Architecture –. AssemblyLanguage programming – simulation using MPLAB IDE - Programming of I/O ports – Addressing modes. PIC Bank switching – Table processing – Timers and its programming – Interrupt programming - Example Programs in all these topics.
Concept of development of single board computers – HW using PIC. Programming PIC using C -Language.

Experiment:

2. Write Assembly language program for solving engineering problems such as serialisation, checksum calculation and verification etc.
3. Download, install and configure MPLAB IDE in a system.
4. Familiarisation of IDE concepts (Various components in IDE, Creation of projects for interworking of different software in IDE), using MPLAB IDE as a tool.
5. Create a project and attach a source code (Assembly and C) to it, compile and run the code without any error reported.
6. Simulate a code by single stepping and validate the logical correctness of the code by verifying the effected registers in each of the step.
7. Using debugging and verification tools of MPLAB IDE , such as logic analyser, stopwatch, variable / IO port watch etc., verify the code for blinking an LED connected to Port-B pin-2 with 0.5 sec ON and 0.5 Sec OFF time.
8. Use ‘Stimulus’ feature of MPLAB IDE to create an external interrupt and verify the corresponding ISR.
9. Solder a simple PIC circuit in the general purpose PCB , Burn the code (for blinking an LED connected to any port pin) in the PIC18Fxxx ROM and execute it.

Microprocessors
Intel 8086 processor- Pin configuration of 8086 – Architecture. 8086Vs Low power RISC processor e.g. PIC18F - 8086 addressing modes – 8086 Instruction set – Assembly Language Programming.
Intel 8086 processor - Interrupts— Minimum and maximum mode –address decoding.

Experiment:

10. Simulate I8086 assembly codes in any of the software tools.

Interfacing ICs
Programmable Peripheral Interface (8255) - Programmable timer (8253)- -Serial communication interface (8251) – DMA controller (8257) - Programmable Interrupt Controller (8259). Connecting the interfacing ICs in a microprocessor-based system.

References:

1. Muhammad Ali Mazidi et al., *PIC Microcontroller and Embedded Systems Using Assembly and C*, Pearson Education, Second Edition, 2021.
2. Lyla B Das, *The x86 Microprocessors*, Pearson Education India, 2nd Edition, 2014.
3. Gaonker R.S.,*Microprocessor Architecture, Programming and applications with 8085*, Penram International, 3rd edition, 1997.
4. Hall D.V., *Microprocessors & Interfacing*, Tata McGraw Hill.
5. Brey B.B., *The Intel Microprocessors - Architecture, Programming & Interfacing*, Prentice Hall, 6th edition, 2004.
6. Liu Y.C. & Gibson G.A., Microcomputer System: The 8086/8088 Family, Architecture Programming and Design, Prentice Hall of India, 2nd edition, 2004.
7. Uffenbeck J.E., *The 8086/8088 Family: Design, Programming & Interfacing, Pearson Education*, 3rd edition, 2002.
8. Ray A.K.& Bhurchandi K.W., *Advanced Microprocessors and Peripherals*, Tata McGraw Hill.
9. Ayala K.J., *The 8051 Micro controller, Architecture, Programming and Applications*, Penram International Publishing (India).
10. Trebel, Walter A Singh, Avtar, *8088 and 8086 microprocessors, Programming Interfacing, Software, Hardware and Aplications*, Pearson Education, 4th edition, 2004,
11. Intel Data Book Vol.1 *Embedded Microcontrollers and Processors*.

EE2003E ELECTRICAL MACHINES I

Pre-requisites: NIL

L	T	P	O	C
3	1	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Discuss the fundamental principles and classification of electromagnetic machines.
CO2: Analyse constructional details and principle of operation of dc machines.
CO3: Evaluate the operation, testing and applications of dc generators and motors.
CO4: Discuss constructional details and principle of operation of transformers.
CO5: Apply knowledge about the testing and applications of transformers.

Electromagnetic Machines
Fundamental principles - classification - generators, motors and transformers - elements of electromagnetic machines - armature windings - single layer winding and double layer winding - lap winding and wave winding - commutator winding - phase winding - single phase winding and three phase winding - MMF of a winding - space harmonics - torque developed in a winding - emf developed in a winding - distribution factor - chording factor.

DC Machines
Construction - principle of operation - magnetic circuit - flux distribution curve in the air-gap - emf equation - armature reaction - demagnetising and cross magnetising ampere turns - commutation - methods of excitation - generators and motors.

DC Generators and Motors
Generators - power flow diagram - circuit model - magnetisation characteristics - process of voltage build up - terminal characteristics - control of terminal voltage - parallel operation - motors - power flow diagram - circuit model - back emf - torque and speed equations - performance characteristics - starting methods - design of starters - methods of speed control - testing - Swinburne's test - Hopkinson's test - separation of losses - retardation test - permanent magnet dc motor - applications.

Transformers
Types and construction - principle of operation - magnetising current - harmonics - ideal and real transformer - dot convention - current and voltage ratio - equivalent circuit - phasor diagram - per unit impedance - losses - efficiency and regulation - all day efficiency - OC and SC tests - Sumpner's test - Parallel operation - tap changing - switching transients - auto transformers - voltage and current relationships - saving of copper - different connections of three phase transformers - notations - Scott connection - cooling methods.

References:

1. Clayton A E & Hancock N N, *Performance and Design of DC Machines*, ELBS,1971.
2. Langsdorf A S, *Theory of DC Machinery*, McGraw Hill, 1999.
3. Nagarath I J & Kothari D P, *Electric Machines*, Tata McGraw Hill, 1999.
4. Say M G, *The Performance and Design of AC Machines*, CBS, 1983.
5. Chapman S J, *Electric Machine Fundamentals*, McGraw Hill, 1999.
6. Toro V D, *Electrical Machines and Power Systems*, Prentice Hall, 1988.

EE2004E ELECTRONIC CIRCUITS – II

Pre-requisites: EE1003E

L	T	P	O	C
3	1	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Design discrete transistor (BJT, JFET, MOSFET) based amplification circuits with given gain and bandwidth.
CO2: Design simple linear signal processing application circuits using general purpose Opamps
CO3: Apply various fixed and adjustable voltage regulator ICs for power supply design.
CO4: Carry out stability analysis on amplifying circuits, evaluate gain margin and phase margin of such circuits and design suitable compensators for achieving specified phase margins in amplifier design context.
CO5: Design audio/medium frequency amplitude-stabilized sinusoidal oscillators using Opamps.
CO6: Design transistorized Bistable, Astable and Monostable circuits for given specifications.

Frequency Response of Discrete Amplifiers (s-domain approach)
Distortion in amplifiers – Non-linear distortion versus linear distortion – linear distortion due to frequency response – amplitude distortion and phase distortion - conditions for distortion-less amplification.Low Frequency response of BJT and FET Amplifiers - Dominant Time Constant in low-frequency range -Selection of Coupling and Bypass Capacitors for BJT (CE, CB, and Emitter Follower) and FET & MOSFET Amplifiers (Common Source) for a given lower cut-off frequency.
High Frequency Response of CE current gain of a BJT- α-cut off and β cut off frequencies - Gain-Bandwidth product-Miller Effect- Dominant Time Constant for high-frequency behavior in a CE Amp, CE Amplifier at high frequencies, CB Amplifier at high frequencies, Emitter Follower at high frequencies- Effect of Miller capacitance on bandwidth in each case
High frequency response of CS-FET and CS-MOSFET amplifiers at high frequencies- Dominant Time Constant for high-frequency behavior in JFET and MOSFET Common Source Amplifiers
Cascade Amplifiers – BJT discrete version, BJT IC version, MOSFET IC version

Basic Opamp Circuits
BJT Differential Amplifiers- Common Mode and Differential Mode gains-CMRR-Current Source Biasing-Offset behavior - Current Sources for biasing inside an IC.
Operational Amplifier - ideal opamp properties-properties of practical opamps (LM741, LM324, LM358, LF351, OP07, TL082)-different stages in an opamp-internally compensated and externally compensated opamps-slew rate - offsets. - Various types of Opamps and their application, Power supply configuration for Opamps, Interpretation of Opamp data sheet – Comparison of LM714 and TL082
Analysis of opamp circuits using ideal opamp model- Concept of Feedback-Negative and Positive Feedback- Loop Gain- Closed Loop Gain - concept of virtual short and its relation to negative feedback –
Offset model of a practical opamp-
Linear Applications of Opamps - Non inverting Amplifier-Gain bandwidth product-Voltage Follower-Inverting Amplifier-Summing Amplifier-Offset analysis of Non inverting and inverting amplifiers-Subtracting Circuit-Instrumentation Amplifier-Voltage to Current Converter for floating and grounded loads-Opamp Integrator-Opamp Differentiator- Series Voltage Regulators-Monolithic Regulators-Three terminal regulators., Fixed and adjustable Voltage Regulators – Voltage Reference ICs
Some Non-linear Applications of Opamps - Comparison Operation, Opamp as a Comparator, Employing Positive feedback in Comparators, Non-Inverting and Inverting Comparators with Hysteresis using Opamps - Astable Multivibrator using Opamp, Square - Triangle Generator, Effect of Opamp Slew rate on Square-Triangle Generator, Linear VCO using Square-Triangle Circuit, Ramp Generator - Precision Half wave and Full wave Rectification.

Feedback Amplifiers, Stability and Oscillators (s-domain approach is envisaged)
Voltage Series Feedback on a single time constant voltage to voltage amplifier - Advantages of negative feedback in a single time constant voltage to voltage amplifier - gain, input and output resistances, rise time, bandwidth, nonlinearity etc- stability and positive feedback in the above amplifier
Voltage Shunt, Current series and Current Shunt topologies and properties – Discrete Transistor Amplifier Examples for various feedback topologies.
Voltage Series feedback on a second order amplifier - Closed Loop poles and loop gain - Transient Response of Closed Loop Amplifier vs Loop Gain
Voltage Series Amplifier with third order open loop amplifier - pole migration to right half of s-plane – Bode Plots of Loop Gain
Barkhausen's criterion for stability of feedback amplifiers - Gain Margin and Phase Margin - Introduction to amplifier compensation-dominant pole compensation- Lag Compensation – Lead-lag Compensation - Sinusoidal Oscillators - Phase Shift Oscillator & Wein's Bridge Oscillator using Opamps – Non-linear Amplitude Limiting in Oscillators – Non-linear Amplitude stabilization of oscillators – Frequency stability in sinusoidal oscillators – Crystal oscillators.
Bistable and Metastable Transistor Circuits – BJT Circuits with positive feedback – Collector coupled Bistable, Astable and Monostable Multivibrator Circuits, Emitter coupled Astable Transistor Circuit.

References:

1. A.S Sedra and K.C Smith, *Microelectronic Circuits,* Oxford University Press, 5th Edn,2009
2. Millman J, *Microelectronic*, 2nd edition, McGraw-Hill, New Delhi,2005.
3. Schilling & Belove, *Electronic Circuits – Discrete and Integrated*, 3rd edition, McGraw-Hill, New Delhi,2006
4. Sergio Franco, *Design with Operational Amplifiers and Analog Integrated Circuits*, Tata McGraw-Hill, New Delhi, 2005
5. National Semiconductor, *Linear Applications Handbook*, 1994
6. Gayakwad R.A, *OPAMPS & Linear Integrated Circuits*, 3rd edition, Prentice Hall of India,1995.
7. Clayton G.B, *Operational Amplifiers*, 5th edition, Oxford ,2004
8. Frederiksen T.M, *Intuitive Operational Amplifiers*, McGraw Hill,1996.

EE2091E ELECTRONICS LABORATORY I

Pre-requisites: NIL

L	T	P	O	C
0	0	2	1	1

Total Practical Sessions: 26

Course Outcomes:

CO1: Use different meters and instruments for measurement of electronic quantities
CO2: Study the characteristics of different semiconductor devices like diode, BJT, FET, UJT etc. experimentally
CO3: Design and test various application circuits using diodes
CO4: Design and test various signal and power amplifier circuits using BJTs and FETs
CO5: Design voltage regulation circuits for given specifications.

List of Experiments:

1. Use of CRO: a) Measurement of current, voltage, frequency, and phase shift.
2. Semiconductor diodes: V-I and transfer characteristics of Si, Ge, and Zener diodes.
3. Characteristics of clipping and clamping circuits using diodes and Zener diodes.
4. Rectifiers and filters with and without shunt capacitors- Characteristics of half-wave, full wave, and bridge rectifiers- Ripple factor, Rectification efficiency, and % regulation.
5. Transistor characteristics in CB and CE configurations - Identification of cut off, active and saturation regions.
6. JFET characteristics in the common source configuration- determination of equivalent circuit parameters.
7. Characteristics of voltage regulators- Design and testing of:
a) Simple Zener voltage regulator
b) Zener regulator with emitter follower output.
8. UJT Characteristics and UJT relaxation oscillator- Design for a particular frequency.
9. RC coupled amplifier using BJT in CE configuration- measurement of gain, input and output impedance and frequency response
10. BJT emitter follower- Measurement of voltage gain, current gain, input impedance, output impedance and load characteristics
11. FET amplifier- Measurement of voltage gain, current gain, input, and output impedance.
12. Power amplifiers- Class AB (complementary symmetry).

Note: Normally the practical classes are administered in two cycles. Depending on the availability of equipment and time, class coordinators may choose the experiments for each cycle.

References:

1. Boylested &Nashesky, *Electronic Devices and Circuit Theory*, 10th Edn, Pearson Education, New Delhi, 2009

Semester-IV

MA45E MATHEMATICS IV

Pre-requisites: MA1001E, MA1011E

L	T	P	O	C
3	1	0	5	3

Total: 39 Lecture sessions

Course Outcomes

CO1: Model managerial problems in industries to linear programming problems and solve it usingvarious techniques and algorithms.

CO2: Model and solve PDEs using analytic methods.

CO3: Apply the basics of probability theory in solving real life problems.CO4: Identify the distribution and transform random variables.

Linear Programming

Linear Programming: Introduction, Optimization model, Formulation and applications, Classical optimization techniques: single and multivariable problems, Types of constraints, Linear optimizationalgorithms: Graphical method, Simplex method, Basic solution and extreme point, Degeneracy, Primal simplex method, Dual linear programs, Duality theory, Dual simplex method, Primal-dual algorithm.

Partial differential Equations

Basic Concepts, Cauchy's problem for first order equations, Quasilinear and nonlinear PDEs of first order, Charpit's Method, Classification of second order partial differential equations, Modelling: Vibrating String, Wave equation, Separation of variables, Use of Fourier Series, D'Alembert's Solution of the wave equation, Heat equation: solution by Fourier series, Heat equation: solution by Fourier Integrals and transforms, Laplace equation, solution of PDEs by Laplace transforms.

Probability Distributions

Probability distributions, Random variables, Expectation, Variance, Moment generating function of arandom variable, Chebyshev's theorem, Binomial distribution, Poisson distribution, Geometric distribution, Hyper-geometric distribution, Normal Distribution, Uniform distribution, Gamma distribution, Beta distribution and Weibull distribution.

Transformation of a random variables, Probability distribution of a function of a random variable, Jointly distributed random variables, Marginal and conditional distributions, Independence, Covariance, Correlation, Bi-variate Normal distribution, Joint probability distribution of functions of random variables.

References:

1. G Mohan and Kusum Deep, Optimization Techniques, New age International Publishers(2009)
2. Wayne Winston, Operations Research - Applications and Algorithms, Cengage Learning Fourth edition (2011).
3. D. Greenspan, Introduction to Partial Differential Equations, Dover Publications; 1st edition,2000.
4. E. Kreyszig, Advanced Engineering Mathematics, John Wiley and Sons, 9th Edn, 2012.
5. S. Ross, A First Course in Probability, 9th Edition, Pearson, 2014.
6. V. K. Rohatgi and A K Md. Ehsanes Saleh, An Introduction to Probability and Statistics, 3rd Edition, John Wiley and Sons, 2015.
7. B. S. Grewal, Higher Engineering Mathematics, 44th Edition, Khanna publishers, 2020.

EE2011E POWER SYSTEMS - I

Pre-requisites: NIL

L	T	P	O	C
3	1	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyse and compare the economics of various electrical energy sources
CO2: Analyse the performance of transmission lines
CO3: Design electrical and mechanical parameters of power system
CO4: Model power systems using single line diagrams and analyse using various load flow methods
CO5: Evaluate and analyse various distribution schemes

Power Generation and Economics
Conventional sources of electrical energy - renewable energy sources - power plant economics - operating costs - load factor - demand factor - diversity factor - plant factor - tariffs- case study

Performance of Transmission Lines
Transmission line parameters – Resistance, Inductance and Capacitance calculations – Single-phase and three phase lines – double circuit lines – effect of earth on transmission line capacitance. GMD and GMR - bundled conductors - transposition - ABCD constants – Ferranti effect
Performance of transmission lines – Transmission line model - Nominal T and π methods of calculations -power flow through a transmission line - Methods of voltage control- Regulation and efficiency – Tuned power lines, Power flow through a transmission line – Power circle diagrams, Introduction to Transmission loss and Formation of corona – critical voltages – effect on line performance – travelling waveform phenomena. Mechanical design of overhead lines – Line supports – Insulators, Voltage distribution in suspension insulators – string efficiency – Stress and sag calculation – effects of wind and ice loading.
Underground cables – Comparison with overhead line – Types of cables – insulation resistance – potential gradient – capacitance of single-core and three-core cables.

Load Flow Studies
Modelling of power system components – single line diagram – per unit quantities– bus impedance and admittance matrix.
Power flow analysis methods: Gauss-Seidel, Newton-Raphson, Fast decoupled methods and DC load flow– computer simulations.

Distribution Systems
Distribution systems – General aspects – Kelvin's Law – AC and DC distribution systems – Calculation of feeder currents and voltages – Techniques of voltage control and power factor improvement – Distribution loss – distributed generation - microgrid – smart grid - simulation models and case study

References:

1. John J.Grainger, W.D. Stevenson: *Power System Analysis*, McGraw-Hill International (Indian Edition) 2017.
2. D P Kothari, I J Nagrath and R K Saket *Modern Power System Analysis*, 5th Edition, 2022.
3. Hadi Saadat, *Power System Analysis*, Tata Mc Graw Hill Pub.Co. 4th Edition 2011.
4. J.C. Das, *Power System Analysis, Short-Circuit Load Flow and Harmonics*, CRC Press., 2nd Edition, 2012.
5. C.L. Wadhwa, *Electrical Power Systems,* 7th Edition, New Age International, 2016.

EE2012E POWER ELECTRONICS

Pre-requisites: NIL

L	T	P	O	C
3	1	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand the requirements of an ideal switch and the characteristics of important power semiconductor switches.
CO2: Analyze power electronic switch-based rectifiers, converters and inverters.
CO3: Select circuit elements required for a Power Electronic system.
CO4: Design a power electronic system for a given application.

Power Semiconductor Switches

Requirements of an Ideal Switch - Power diodes - Basic structure and static & dynamic characteristics - various types - Thyristors - basic structure - static and dynamic characteristics - device specifications and ratings - methods of turning on - gate triggering circuits - methods of turning off - commutation circuits. IGBTs - Basic structure and V-I characteristics. MOSFETs - Basic structure and V-I characteristics. Gate Driver Circuits for IGBTs and MOSFETs. Snubber Circuits- Turn OFF snubber, Turn ON snubber.

Controlled Rectifiers
Line frequency phase-controlled rectifiers using SCR
Single Phase – Half wave-controlled rectifier with R and RL loads – Full wave half controlled and fully controlled converters with continuous and constant currents - Input side harmonics and power factor - Effect of source inductance.
Three Phase - Half wave-controlled rectifier with R and RL loads - Full wave fully controlled converters with continuous and constant currents - Input side harmonics and power factor - Effect of source inductance.

Inverters
Introduction to Inverters - Single Phase Inverters – Half Bridge Inverters and Full Bridge Inverters – Square wave operation – Introduction to PWM – Sinusoidal PWM - Unipolar PWM – Bipolar PWM –
Three Phase Inverters – Square Wave Operation (180^0 mode) – SPWM in 3-Phase Inverters – Third Harmonic Injection
Grid-Tied Inverters – (Only Single-Phase case is envisaged here)
Single-phase Full-bridge Bilateral AC-DC Converter connected to grid through an inductance – Hysteresis current control based strategy for AC to DC Power flow and DC to AC Power flow – Advantages and disadvantages of hysteresis control – Power flow control by Synchronous Link based Voltage Source Inverter Control – Applications : Rectification with unity power factor in the AC side, Battery Charging, Battery Energy Storage Systems, Renewable Energy Source Interfacing to Grid, Static VAr Compensation, Active Harmonic Filtering, Introduction to ac and dc drives

DC – DC Converters
Design of Inductors – Design of Transformers - Capacitors for Power Electronic Application - Thermal Design of Heat Sinks for Power Switching Devices
Linear DC-DC Converters (Regulators); Switched Mode DC-DC Converters (Non isolated) - Buck Converter - Boost Converter – Buck-Boost Converter;

References:

1. L Umanand, *Power Electronics: Essentials and Applications*, Wiley India Pvt. Limited, 2009
2. Robert W. Erickson, Dragan Maksimović, *Fundamental of Power Electronics*, Springer Link, Third edition
3. Ned Mohan, *Power Electronics*., John Wiley and Sons, 2nd edition, 1995.
4. Rashid, *Power Electronics*, *Circuits Devices and Applications*, Pearson Education, 3rd edition, 2004.

5. G.K.Dubey, *Thyristorised Power Controllers*, Wiley Eastern Ltd, 1993.
6. Dewan & Straughen, *Power Semiconductor Circuits*, John Wiley & Sons, 1975.
7. Cyril W Lander, *Power Electronics*, Mc Graw Hill, 3rd edition, 1993.

EE2013E ELECTRICAL MACHINES - II

Pre-requisites: NIL

L	T	P	O	C
3	1	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Acquire knowledge about the constructional details and principle of operation of alternators.

CO2: Acquire knowledge about the working of synchronous machines as generators and motors.

CO3: Acquire knowledge about the constructional details and principle of operation of induction motors.

CO4: Acquire knowledge about the speed control, testing and applications of induction motors.

CO5: Acquire knowledge about the generalized machine theory and simulation methods.

Alternators
Construction - principle of operation - type and selection - armature reaction - voltage regulation - predetermination of voltage regulation - EMF method - synchronous reactance and short circuit ratio - MMF method - Potier method - phasor diagrams - two reaction theory - modified phasor diagram - analysis by two reaction theory - sudden short circuit - current waveforms - transient and sub transient reactance - slip test - DC excitation - static excitation - brush less excitation and self excitation - measurement of losses.

Synchronous Machines
Power angle characteristics of cylindrical rotor and salient pole machines - reluctance power - active and reactive power control - load sharing upon parallel operation - effect of armature reactance - automatic synchronizing - effect of change in fuel supply and excitation - alternator connected to infinite bus - governor characteristics - synchronizing power and torque - phasor diagram for two identical generators in parallel - locus of generated voltage for constant real power and variable excitation - automatic voltage regulators - synchronous motor - principle of operation - equivalent circuit - phasor diagram - torque and power relations - effect of load changes on synchronous motor - mechanical load diagram - armature current as function of power developed and excitation - V curves - inverted V curves - minimum excitation for given power - hunting - periodicity of hunting - suppression - different starting methods.

Induction Machines
Three phase induction motors - construction - principle of operation - rotor MMF and production of torque - slip and frequency of rotor current - phasor diagram - equivalent circuit - mechanical power developed - maximum torque - torque slip characteristics - losses and power flow - single phasing - no-load and blocked rotor tests - circle diagram - effect of deep bar and double cage rotors - effects of air gap flux harmonics - cogging and crawling - starting methods for three phase induction motors - direct on line starting - auto transformer starting - star delta starting - rotor resistance starting - starters and contactors - speed control - basic methods - voltage control - frequency control - rotor resistance control - pole changing - static frequency conversion and slip power recovery scheme - line excited and self excited induction generators - single phase induction motors - double revolving field theory - equivalent circuit - starting methods of single phase induction motors - applications of all types of induction motors.

Generalised Machine Theory
Generalised machine theory - machine as a circuit - model parameters - conventions - models for dc machines, synchronous machines, induction machines and transformers - introduction to digital simulation of systems comprising of machines.

References:

1. Langsdorf A S, *Theory of DC Machinery*, McGraw Hill, 1999.
2. Nagarath I J & Kothari D P, *Electric Machines*, Tata McGraw Hill, 1999.
3. Say M G, *The Performance and Design of AC Machines*, CBS, 1983.
4. Chapman S J, *Electric Machine Fundamentals*, McGraw Hill, 1999.
5. Toro V D, *Electrical Machines and Power Systems*, Prentice Hall, 1988.

EE2014E CONTROL SYSTEMS – I

Pre-requisites: NIL

L	T	P	O	C
3	1	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Represent the dynamical systems using transfer function models
CO2: Analyze the system response and stability using time-domain methods
CO3: Analyze the system response and stability using frequency-domain methods
CO4: Design the compensators for dynamical systems using time domain and frequency domain techniques
CO5: Analyze the system response and design compensators using simulation tools.

Modelling of Dynamical Systems

Dynamic Systems Modelling - Differential equation model and Transfer function model of LTI SISO and MIMO systems - Development of models for Electrical, Mechanical, Electromechanical, Pneumatic Liquid level, and Thermal systems. Actuators - Electrical, Mechanical, Electromechanical, Pneumatic etc. Open loop and Closed loop transfer function- Block diagram representation- Block diagram reduction - Signal flow graphs – Mason's gain formula.

Time-domain analysis

Time domain analysis - Transient response analysis- First order systems- Initial condition response - Impulse response- Step input response-Time constant - Second order system response- Transient response specifications- Response of Higher order systems - Steady state error and error constants - dynamic error constants.
Concept of stability of LTI systems -BIBO stability- Characteristic equation - Effect of feedback on closed loop stability - Routh Hurwitz criterion - Root locus techniques

Frequency domain Analysis

Frequency domain methods - Sinusoidal transfer function – Frequency response - Frequency domain specifications - peak resonance and resonant frequency- correlation with time domain specifications.
Polar plot, Nyquist plot and Bode plot for stability analysis - relative stability - gain margin and phase margin – Nyquist Stability criteria - Bandwidth and cut off frequency – Transfer function from Bode plot

Design of controllers and Compensators

Conventional control laws - P, PI, PD and PID controllers – Tuning methods - Effect of P, PI, PD and PID controllers on system response of First order and Second order systems – Advanced PID controllers for industrial processes - Lead, Lag and Lead lag compensators, Root locus techniques for Compensator design, Compensator design using Frequency domain techniques.

References:

1. Katsuhiko Ogata, *Modern Control Engineering*, 5th edition, Pearson Prentice Hall, 2015.
2. Benjamin C Kuo, *Automatic Control Systems, 9th ed*, Oxford University Press, 2014.
3. A. Ramakalyan, *Control Engineering: A Comprehensive Foundation*, S.Chand (G/L) & Company Ltd, *2003.*
4. Norman S Nise, *Control Systems Engineering*, Wiley, 7th Edition, 2014
5. M Gopal and Nagrath, *Control Systems Engineering*, 7th ed., Tata McGraw Hill, 2021
6. Karl J. Astrom and T. Hagglund, *PID Controllers: Theory, Design and Tuning,* 2nd edition, 1995
7. Hassan K Khalil, *Control Systems: An introduction,* Michigan State University, 2023

EE2092E ELECTRICAL MACHINES LAB I

Pre-requisites: EE2003E Electrical Machines-I

L	T	P	O	C
0	0	2	1	1

Total Practical Sessions: 26

Course Outcomes:

CO1: Acquire hands on experience of conducting various tests on dc machines.

CO2: Acquire knowledge about the various methods for the performance analysis of dc machines.

CO3: Acquire hands on experience of conducting various tests on transformers.

CO4: Acquire knowledge about the various methods for the performance analysis of transformers.

List of Experiments:

1. Determination of the open circuit characteristic of a dc shunt generator and its analysis.
2. Load test on a dc shunt generator and the determination of its internal and external characteristics.
3. Break test on dc shunt and series motors, determination of the performance characteristics and analysis.
4. Swinburne's test on a dc shunt motor and predetermination of efficiency of the machine.
5. Hopkinson's test on a pair of dc shunt machines and predetermination of their efficiencies.
6. Retardation test on a dc shunt machine and separation of losses.
7. No load test on a dc machine and separation of losses.
8. OC and SC tests on a single-phase transformer and the predetermination of its efficiency and regulation.
9. Separation of losses in a single-phase transformer.
10. Sumpner's test on a pair of single-phase transformers and the predetermination of efficiency and regulation.
11. Polarity test on single phase transformers and three phase connections of the same.

References:

1. Clayton A E & Hancock N N, *Performance and Design of DC Machines*, ELBS,1971.
2. Nagarath I J & Kothari D P, *Electric Machines*, Tata McGraw Hill, 1999.
3. Say M G, *The Performance and Design of AC Machines*, CBS, 1983.
4. Toro V D, *Electrical Machines and Power Systems*, Prentice Hall, 1988.

EE2093E ELECTRONICS LABORATORY II

Pre-requisites: NIL

L	T	P	O	C
0	0	2	1	1

Total Practical Sessions: 26

Course Outcomes:

CO1: Design and test various basic linear application circuits using Opamps

CO2: Design and test various signal comparison operation circuits using Opamps and Comparators

CO3: Design and test various waveform generation circuits using Opamps, Comparators and IC packages

CO4: Design and test various combinational logic circuits and systems

CO5: Design and test various sequential logic circuits and systems

List of Experiments:

1. OPAMP circuits - design and set up of inverter - scale changer - adder - non-inverting amplifier integrator and differentiator using TL082 or LM741
2. OPAMP comparator - design and set up of Schmitt trigger - window comparator
3. Phase shift and Wein's bridge oscillator with amplitude stabilization using OPAMPs
4. Waveform generation - square, triangular and saw tooth wave form generation using OPAMPs
5. Precision rectification - absolute value and averaging circuit using OPAMPs
6. Astable Multivibrator using BJTs – set up a collector coupled astable circuit and compare its performance with that of a emitter coupled astable circuit designed for same frequency.
7. Using UP DOWN COUNTER and a DAC Ics, generate triangular waveform
8. (a) Using CD 4047 IC, design and set up gated/ungated astable and monostable multivibrators

   (b) Using CD 4093 Schmitt NAND IC, design and set up astable and monostable multivibraors
9. Design of Half adder and half subtractor circuits with NAND gates using mode control
10. (a) Design and realization of ripple counter using JK flip-flop

    (b) Cascading of synchronous counters

    (c) Design and realization of Johnson & Ring counter using (a) JK flip flop (b) shift register
11. Synchronous UP/DOWN counter design and realization
12. (a) Design a Function Generator and VCO using TL082 and MPY634.

    (b) Design a AGC and AVC using TL082 and MPY634 for a given peak amplitude of sine wave.
13. (a) Design a low drop out regulator using TL082 for a given voltage regulation characteristics and compare the characteristics with TPS7250 IC.

    (b) Design a switched mode power supply that can provide a regulated output for a given input range using the TPS40200 IC.

Note: Depending on the availability of equipment and time, class coordinators may choose the experiments.

References:

1. A.S Sedra and K.C Smith, *Microelectronic Circuits*, Oxford University Press, 5th Edn,2009.
2. Texas instrument – lab manual
3. Navas K A, Electronics Lab Manual : Volume I, Fifth Edition, PHI Learning Pvt. Ltd

Semester-V

EE3001E DIGITAL SIGNAL PROCESSING

Pre-requisites: NIL

L	T	P	O	C
3	1	0	5	3

Total Sessions: 39

Course Outcomes:

CO1: Analyze discrete time systems using time domain and frequency domain methods.
CO2: Design and validate linear phase FIR systems for various digital signal processing tasks.
CO3: Design IIR and FIR Filter structures for common filtering applications.
CO4: Analyze the spectrum of periodic CT waveforms using Digital Spectrum Analyzer and interpret the results.
CO5: Design Digital Filters by Block Convolution.

Fourier Analysis of DT Signals and Systems
Discrete-time (DT) signals and LTI-DT Systems – description by finite difference equations, decomposition of the analysis problem stated by $\sum_{i=0}^{N} a_i y[n-i] = \sum_{i=0}^{M} b_i x[n-i]; n \geq 0 \text{ and } a_o = 1,$ with $y[-1] = y_{-1}; y[-1] = y_{-2}; \ldots \; y[-N] = y_{-N}$ into Zero-input problem + Zero-state problem format suitable for applying superposition principle – Zero-input response (ZIR) and Zero-state response (ZSR) – Interpretations of ZIR and ZSR – Principle of superposition as applied to ZSR, ZIR and Total Response.
ZIR of LTI-DTS – Solution and properties of ZIR – Characteristic equation of a FDE – Natural frequencies, Location of natural frequencies in signal plane – stability of LTI-DTS and Unit Circle in signal plane.
ZSR of LTI-DTS for standard inputs of type $x[n]$ for n ≥ 0
Eigen functions of an FDE - z^n as eigen function of a LTI-DTS – condition of dominance - sinusoidal steady-state frequency response function (FRF) – Determination of FRF from FDE coefficients – Properties of FRF
Sinusoidal steady-state response from convolution summation – relation between FRF and Impulse Response coefficients - sinusoidal steady-state response as the primary and sufficient response of a LTI-DTS
Review of Fourier Transform theory for CT Signals – Sampling – Sampling Theorem – Aliasing – Band limiting – Interpolation – Ideal Interpolator – Practical interpolators – ZOH and First Order Hold - Realization of a CT frequency response by CT to DT + DT frequency response + DT to CT chain.
Expansion of an arbitrary $x[n]$ in terms of DT Sinusoids– Periodic sequences – Discrete Fourier Series (DFS) and properties, solution of LTI-DTS with periodic inputs using DFS and FRF –
Expansion of a Finite Duration Sequence (FDS) $x[n]$ in terms of DT Sinusoids - periodic replication of an FDS – DFS of periodic replication of an FDS – Limit of DFS as period of replication is sent to ∞ - Discrete-Time Fourier Transform (DTFT) – Properties of DTFT – Extension for general aperiodic $x[n]$ - conditions for existence of DTFT – Use of DTFT in solving LTI-DTS with aperiodic inputs.

Z-Transforms and Transfer Function
Expansion of an arbitrary $x[n]$ in terms of generalized complex exponential sequences of z^n type – Z-transform and its interpretation – Inverse Integral and Convergence – Inverting Z-transforms -Properties of Z-transform –
Use of unilateral Z-transform in solving FDE with initial conditions – System Transfer Function – Poles and Zeros – Stability and Unit Circle in z-plane – FRF from transfer function – Geometrical determination of FRF from z-domain pole-zero plot –
All-pass systems, Minimum phase systems, FIR systems and generalized linear phase frequency response – Type-1, Type-2, Type-3 and Type-4 Linear Phase FIR Systems and applications.

IIR and FIR Filter Design
IIR Filter design by transformation of Analog filter functions – Butterworth functions for LPF, HPF , BPF and Notch filters –

Transforming analog function to discrete transfer function – Forward and backward difference transformations – Impulse invariant transformation – Bilinear transformation – pre-warping –
Properties of FIR filters – FIR filter design by Windowing – comparison between IIR and FIR filters
Basic structures for IIR and FIR Systems – Direct forms – Cascade forms – Parallel forms.
Finite word length effects in DSP – zero-input limit cycles in fixed point implementations – limit cycles due to overflow

DFT, FFT and Applications
Sampling of DTFT of a Finite Duration Sequence– Discrete Fourier Transform (DFT) – Inverse DFT (IDFT) – properties of DFT and IDFT –
Sampling of DTFT of a Infinite duration sequence – IDFT of these samples – aliasing– Linear Convolution and Circular Convolution – Relation between them for different combinations of sequences –
Evaluation of Linear Convolution through Circular Convolution using DFT – Implementation of LTI-DTS by DFT – Block Convolution and latency - Overlap-save and Overlap-add methods –
Computation of DFT – FFT Algorithm – Radix-2 DIT FFT – Radix-2 DIF FFT – Butterfly computations – bit reversed order – in-place computations –
Spectral Analysis of a periodic CT signal by FFT – resolution – leakage – picket-fence effect - interpretation of reported spectral data and pitfalls

References:

1. John G. Proakis, and Dimitris G. Manolakis, Digital Signal Processing, 4th ed., Pearson Education India Pvt. Ltd., 2013.
2. Alan V Oppenheim, Ronald W. Schafer, Discrete-Time Signal Processing, 3rd ed., Pearson Education India Pvt. Ltd., 2014.
3. Sanjit K Mitra, Digital Signal Processing: A computer-based approach, 4th ed., McGraw-Hill Education, 2013
4. Lonnie C Ludemann, Fundamentals of Digital Signal Processing, Wiley, 2009
5. Antoniou, A. Digital signal processing: signals, systems, and filters., McGraw-Hill Education, 2005

EE3002E POWER SYSTEMS – II

Pre-requisites: NIL

L	T	P	O	C
3	1	0	5	3

Total Sessions: 39

Course Outcomes:

CO1: Examine and analyse the behaviour of faulted power systems
CO2: Design protection schemes for power systems
CO3: Select appropriate relay settings for overcurrent and distance relays.
CO4: Interpret generation control and economic despatch methods of interconnected systems
CO5: Determine and analyse various stability issues of power system
CO6: Analyse quenching mechanisms used in various circuit breakers

Fault Analysis
Fault studies – Symmetrical fault analysis, Analysis through impedance matrix, Current limiting reactors. Fault analysis – Review of symmetrical components - Unsymmetrical short circuit analysis - LG, LL, LLG; Fault parameter calculations – Open circuit faults.

Economic dispatch, AGC & AVR
Economic dispatch of thermal plants - B-coefficient - optimal load flow solution –unit commitment-speed governing of turbo generator –- load sharing and governor characteristics-load frequency control of single and multi area systems - implementation of Economic Dispatch and Automatic Generation Control - automatic voltage regulation – EMS, SCADA, hydro thermal scheduling – computer simulations.

Power System Stability
Stability studies – Steady state and transient stability– Swing equation - Equal area criterion – multi-machine stability analysis- Voltage stability problem: causes and improvement methods-introduction to power system security and reliability

Switchgear and Protection

Protection against over voltages – Causes of over voltage, Ground wires, Surge absorbers and diverters. Earthing - types. Insulation co-ordination. Theory of arcing - types of circuit breakers and fuses – rating and comparison, RRRV, Reclosers and Isolators - Resistor switching and capacitor switching
Relays – General classification, Principle of operation, types, characteristics, Torque equation, Relaying Schemes, Relay Co-ordination. Apparatus and line protection – Overcurrent protection – Distance protection - Differential protection. Relay settings for overcurrent and distance relays. Generator protection – Transformer Protection – Incipient fault – Feeder and Bus bar protection.
Introduction to Static relays – Digital relays - Microprocessor based relays –Basics of Numerical relays.

References:

1. Stanley H. Horowitz, Arun G. Phadke, and Charles F. Henville. ‘Power System Relaying’, 5th Edition, John Wiley & Sons 2022
2. D N Vishwakarma, Badri Ram, and Soumya R Mohanty. ‘Power System Protection and Switchgear’, 3rd Edition. McGraw Hill, 2022
3. Elgerd.O.I, ‘Electric Energy System Theory – An Introduction’, Tata McGraw Hill, New Delhi, 2013
4. Allen J. Wood, Bruce Wollenberg and Gerald B. Sheble “Power System Generation, Operation and Control’, 3rd Edition John Wiley and Sons, 2013
5. W.D. Stevenson: Elements of Power system Analysis, McGraw Hill International Student 4th Edition 2015
6. John J.Grainger , W.D. Stevenson: Power System Analysis, McGrawHill International (Indian Edition) 2017.
7. D.P. Kothari and I.J. Nagrath, Power System Engineering, 3rd Edition Tata McGraw-Hill Pub. Co., New Delhi, 2019.

EE3003E CONTROL SYSTEMS - II

Pre-requisites: NIL

L	T	P	O	C
3	1	0	5	3

Total Sessions: 39

Course Outcomes:

CO1: Develop state space models for continuous and analyze their time response
CO2: Design of controllers and observers for dynamical systems using state feedback
CO3: Model, analyse the performance and design controllers for discrete time dynamical systems
CO4: Analyse the characteristics and asses the stability of nonlinear dynamical systems
CO5: Evaluate the performance of dynamical systems using simulation tools

State space analysis
Dynamic Systems Modelling in State Space - State space models from Transfer function - Transfer function from state space model- Similarity transformations and Canonical forms – Controllable, Phase variable, diagonal, Jordan canonical forms - Eigenvalues and eigenvectors - system stability - Solution of state equations of LTI systems- State transition matrix – Computation of state transition matrix using Laplace transform and Cayley Hamilton methods

State space based controller design
State Space design - Controllability and Observability from state space models – Kalman test – Gilbert test – Duality- Pole zero cancellation - design of state feedback controllers from time domain specifications – dominant poles - pole placement - Ackerman's formula– design of full order and reduced order observers – separation principle.

Introduction to digital control systems
[Review of data conversion and quantization - Sampling process - Mathematical modeling - Data reconstruction and filtering of sampled signals - Hold devices - z transform analysis - Relationship between s plane and z-plane-No class time alloted]
Digital control systems - Pulse transfer function - Difference equation - Solution by z-transform - Stability of linear digital control systems - Stability tests – Jury's test – Routh Hurwitz based stability analysis using bilinear transformation.
State space models for digital control systems - Controllability and observability of digital control systems – Loss of controllability and observability on discretization - Pole placement using state feedback for digital control systems.

Analysis of nonlinear systems
Nonlinear phenomena - different types of nonlinearities and their occurrence – Equilibrium points - Linearization - classification of equilibrium points - stability of equilibrium points - Phase plane analysis - limit cycles in phase plane - existence of limit cycle – Poincare Bendixon theorems – Poincare Index - stability of limit cycles.
Stability of non-linear systems - Lyapunov's first and second methods – Variable gradient method for generation of Lyapunov function - Lyapunov method for linear systems – Lyapunov equation.
Nonlinear feedback systems - Filter hypothesis - Describing functions - amplitude and frequency of limit cycles.

References:

1. Katsuhiko Ogata, Modern Control Engineering, 5th edition, Pearson Prentice Hall, 2015.
2. I J Nagrath and M Gopal, Control Systems Engineering, 7rd ed., Tata McGraw Hill, 2021.
3. M.Gopal, Digital control and State Variable methods, 4th ed, Tata McGraw –Hill, 2017
4. Benjamin C Kuo, Digital Control Systems, 2nd edition, Oxford University Press, 1995.
5. Hassan K Khalil, Nonlinear Systems, 3rd edition, Prentice Hall International (UK), 2002.
6. S. Strogatz, Nonlinear Dynamics and Chaos, 2nd Edition, CRC Press, 2018
7. S. Wiggins, Introduction to Applied Nonlinear Dynamical Systems and Chaos, Springer Verlag, 1990.
8. K P Mohandas, Modern Control Engineering, Revised Edition, Sanguine Pearson, 2010
9. Hassan K Khalil, Control Systems : An introduction, Michigan State University, 2023

EE3004E ANALOG INTEGRATED CIRCUITS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Sessions: 39

Course Outcomes:

CO1 : Select the right Opamp for a given linear and non-linear application problems.
CO2 : Develop insight into working of BJT and MOSFET based Opamps.
CO3 : Design simple waveform generation circuits using Opamps and Comparators
CO4 : Apply analog building blocks like PLL, Multiplier ICs, RMS-DC Converters etc., to build signal processing subsystems.
CO5 : Draw up specifications for a filter design problem and design custom-made Single OpampBiquad cascade filters to satisfy the specifications.
CO6: Apply standard S/H Amplifiers and data Converters for building signal conversion systems.

Review of Linear Applications of Opamps
[Revision to be done by student outside class hours - Ideal Opamp Properties, Ideal Opamp versus Practical Opamp, Nonlinear Operation Modes of an Opamp, Virtual Short and Zero Input Current Principles in Ideal Opamp, The IOA Model, Analysis of Opamp Circuits Using IOA Model, Non-Inverting Amp, Inverting Amp, Non-Inverting Summer, Inverting Summer, The Offset Model for a Practical Opamp, Offset Analysis of Non-Inverting and Inverting Amps]
The Subtractor Circuit, Effect Resistor Tolerances on Subtractor Circuit.
Effect of Finite Gain, Finite Input Resistance and Non-Zero Output Resistance on Non-Inv Amp and Inverting Amp, Effect of Parasitic Capacitances, Guidelines for Resistor Selection in Opamp Circuits.
Internally Dominant Pole Compensated Opamp – Single time constant model for such an Opamp- Effect of Frequency Response of Opamp on Non-Inv Amp and Inv Amp, Cascading First Order Stages for Increasing Bandwidth, Linear Distortion due to frequency response of amplifiers.
The Integrator Circuit and its Offset Behaviour, The Differentiator Circuit, Effect of Finite GBP of Opamp on Differentiator, Various Instrumentation Amplifiers, Voltage to Current Converters for Grounded and Floating Loads, Howland Current Pump, Deboo Integrator

Inside an Opamp
Internal Analysis of 741 IC – Current Mirrors, Bias Analysis of Input Stage, Common mode feedback, Bias Analysis of Intermediate Stage and Output Stage, Output Current Limiting, Signal Analysis of Input and Intermediate Stages, Signal Analysis of Output Stage and Current Limiting, Transition Frequency, Relation between transition frequency and slew rate, Gm reduction method for improving slew rate.
Bias and Small Signal Analysis of a typical two-stage CMOS Opamp,
Bias and Small Signal Analysis of a typical folded cascode CMOS Opamp

Comparison Operation & Function Generation
Comparison Operation- Opamp as a Comparator, Limitations of Opamp as a Comparator, Employing Positive feedback in Comparators, Non-Inverting and Inverting Comparators with Hysteresis using Opamps, LM311 IC, Regenerative Comparator Designs using LM311 –
Astable Multivibrator using Opamps and Comparators
Square - Triangle Generator- Effect of Opamp Slew rate on Square-Triangle Generator, Linear VCO using Square-Triangle Circuit, Free-running and Triggered Ramp Generator, Converting Triangle to Sine by Wave Shaping, Grounded Capacitor VCO, ICL 8038 Function Generator IC, Triangle to Sine by Logarithmic Waveshaping, Emitter Coupled VCO, XR2208 Function Generator IC
Voltage to Frequency Conversion, Frequency to Voltage Conversion – Study of VFC32 IC

Some Analog Building Blocks
IC Multipliers - Log-Antilog Amplifiers, Multiplier Based on Log-Antilog Amplifiers, True RMS IC,.
Transconductance Type IC Multipliers - Analog Multiplier MPY634 and applications, AGC and AVC using TL082 and MPY634 -
Phase Locked Loops-Principles-Lock and Capture Ranges-Capture Process-Loop Filter-PLL dynamics under locked condition-study of NE564 and CD 4046-Applications of PLL in signal reconstruction, noise rejection, frequency multiplication, frequency synthesis, FSK demodulation, FM demodulation, line synchronization etc.
Operational Transconductance Amplifiers - Basic Structure of OTA, OTA with Linearising Diodes, Various Applications of OTAs - Voltage Controlled Amplifier, Voltage Controlled Resistor, Four Quadrant Multiplier, Voltage Controlled Filters etc.

Signal Conditioning and Conversion

Signal Filtering -Ideal Filters versus Practical Filters, Butterworth LPF Function, Second Order Sallen-Key LPF Section, Design of Butterworth High Pass and Narrow Band Pass Filters by Frequency Transformation, Sallen-Key High Pass Circuit, Deliyannis-Friend Band Pass Circuit, Multiple Opamp Biquad Filters, KHN Filter, Universal Active Filter, Tow-Thomas Filter, Sinusoidal Oscillator using a Narrow Band Pass Filter.

Signal Conversion - Analog Switches- Peak detector and Sample and Hold Amplifier Circuits-Data Conversion Fundamentals-D/A Conversion-Weighted Resistor DAC- R/2R Ladder DAC-Current Switching DAC-Multiplying DAC-Bipolar DACs-A/D conversion-Quantizer Characteristics-Single Slope and Dual Slope ADCs-Counter Ramp ADC-Tracking ADC - Successive Approximation ADC-Simultaneous ADC.

References:

1. A.SSedra and K.C Smith, ".Microelectronic Circuits"., Holt Saunders International Edition-3,1989
2. D.H. Sheingold, ".Nonlinear Circuits Handbook"., Analog Devices Inc. 1976
3. Clayton , ."Operational Amplifiers"., Butterworth Publications,1979
4. Sergio Franco, " Design with Operational Amplifiers and Analog Integrated
5. Circuits"., Mc Graw Hill, 1988
6. M.E Van Valkenburg, "Analog Filter Design"., Oxford University Press 2001
7. Analog Devices Inc , "RMS to DC Conversion Application Guide".
8. Analog Devices Inc., "A Designers. Guide to Instrumentation Amplifiers".

EE3091E POWER ELECTRONICS LAB

Pre-requisites: NIL

L	T	P	O	C

0	0	2	1	1

Total Sessions: 39

Course Outcomes:

CO1: Study the characteristics of different power semiconductor devices like SCR, MOSFET, IGBT etc. experimentally
CO3: Design and test single phase uncontrolled and controlled rectifiers for R and RL loads.
CO4: Design and test non-isolated switched mode DC-DC converters.
CO5: Design and test single phase inverters.

Syllabus / List of Experiments:

1. Study of single-phase uncontrolled rectifiers (half wave and full wave) using C filter and LC filters.
2. Study of V-I characteristics of SCR and design of R, RC triggering circuits for SCR.
3. Study of SCR based single-phase AC voltage controller using R and RC triggering.
4. Study of V-I characteristics, switching characteristics and power loss (conduction and switching loss) of MOSFET.
5. Study of V-I characteristics, switching characteristics and power loss (conduction and switching loss) of IGBT.
6. Design and implementation of gate driver circuit for a MOSFET- (i) non-isolated driver using transistors, (ii) isolated driver using TLP250 gate driver IC
7. Study of line regulation and load regulation in a buck converter.
8. Study of conduction modes in a buck-boost converter using (i) switching frequency variation, (ii) inductance variation.
9. Single-phase semi-converter: Performance study for R and RL loads.
10. Single-phase full-converter: Performance study for R and RL loads.
11. Single-phase square wave inverter: Study the effect of variation in DC bus voltage and duty cycle.
12. Single-phase sine PWM inverter: Study the effect of variation in DC bus voltage and modulation index.

Note: Normally the practical classes are administered in two cycles. Depending on the availability of equipment and time, class coordinators may choose the experiments for each cycle.

References:

1. L Umanand, Power Electronics: Essentials and Applications, Wiley India Pvt. Limited, 2009
2. Robert W. Erickson, Dragan Maksimović, Fundamental of Power Electronics, Springer Link, Third edition

EE3092E ELECTRICAL MACHINES LAB II

Pre-requisites: NIL

L	T	P	O	C

0	0	2	1	1

Total practical Sessions: 26

Course Outcomes:

CO1: Acquire hands on experience of conducting various tests on alternators.
CO2: Acquire knowledge about the various methods for the performance analysis of alternators.
CO3: Acquire hands on experience of conducting various tests on induction machines.
CO4: Acquire knowledge about the various methods for the performance analysis of induction machines.

Syllabus / List of Experiments:

1. No load and blocked rotor tests on a 3-phase squirrel cage induction motor, determination of its equivalent circuit and performance analysis by drawing the circle diagram.
2. No load and blocked rotor tests on a 3-phase slip ring induction motor, determination of its equivalent circuit and performance analysis by drawing the circle diagram.
3. No load and blocked rotor tests on a single phase induction motor, determination of its equivalent circuit and performance analysis.
4. Load test on a 3-phase squirrel cage induction motor and its performance analysis.
5. Load test on a 3-phase slip ring induction motor and its performance analysis.
6. Operation of a dc machine coupled induction machine as an induction generator and its performance analysis.
7. Speed control of an Induction motor by variable frequency method.
8. Predetermination of voltage regulation of a 3-phase alternator by EMF and MMF methods.
9. Predetermination of voltage regulation of a 3-phase alternator by ZPF method.
10. Slip test on a salient pole alternator and the predetermination of voltage regulation.
11. Synchronization of a 3-phase alternator to the supply mains and plotting of V-curves and inverted V-curves.

References:

1. Nagarath I J & Kothari D P, Electric Machines, Tata McGraw Hill, 1999.
2. Say M G, The Performance and Design of AC Machines, CBS, 1983.
3. Toro V D, Electrical Machines and Power Systems, Prentice Hall, 1988.

Semester-VI

EE3011E INTRODUCTION TO COMMUNICATION SYSTEMS

Pre-requisites: NIL

L	T	P	O	C
3	1	0	5	3

Total Sessions: 39

Course Outcomes:

CO1: Become familiar enough with mathematical concepts on signals and random processes to understand various design choices employed in Analog & Digital Communication Systems aimed at optimizing energy and bandwidth resources optimally.
CO2: Acquire knowledge on various Amplitude Modulation Techniques employed in practice and become familiar with related hardware.
CO3: Acquire knowledge on various Angle Modulation Techniques employed in practice and become familiar with related hardware.
CO4: Acquire knowledge on Pulse Amplitude Modulation and Pulse Code Modulation Systems.
CO5: Become familiar with various line codes used in Digital Base Band Transmission and develop capability to calculate bit error probability under commonly employed detection schemes.
CO6: Become familiar with various Keying Schemes used in Digital Carrier-Based Transmission Systems and develop capability to calculate error probability under commonly employed detection schemes.

Introduction & Mathematical Preliminaries
The Communication Process: Primary Communication Resources, Sources of Information, Communication Channels, Modulation Process, Analog & Digital Types of Communication, Block Diagram of a Communication System [Ref 2]
Review of Exponential Fourier Series of Periodic Waveforms, Power Spectral Density (PSD) of Periodic Waveforms, Fourier Transform description of Finite Energy Signals, Energy Spectral Density (ESD) of Finite Energy Signals, Parseval's Theorem, Effect of Linear Filtering on PSD and ESD [No class hours, students are expected to revise this portion using Ref. 1, Chapter 1]
Correlation between waveforms: Power and Cross Correlation, Autocorrelation, Relation between autocorrelation and PSD/ESD [Ref. 1, Chapter 1]
Signal space concepts: expansions in orthogonal functions, Gram-schmitt procedure, and correspondence between signals and vectors, signal distance and distinguishably of signals [Ref. 1, Chapter 1]
Sampling and Reconstruction of Analog Signals: Nyquist Sampling Theorem, Ideal Reconstruction Filter
Introduction to random process: Stationarity, Mean, Correlation and Covariance functions, Ergodic Process, Effect of linear filtering on random process, PSD of a random process, Gaussian Process, the Error Function, properties of White Gaussian Noise. [Refs. 1 & 2]
Noise in communication channels: thermal noise, shot noise, partition noise, flicker noise, avalanche noise, burst noise, BJT noise, FET noise, Signal to Noise ratio, SNR for tandem connection, noise factor [Ref. 3]

Continuous-Wave Modulation Systems
Carrier-based modulation and Frequency Division Multiplexing
Amplitude Modulation: AM Index, Frequency spectra of AM signal, DSBSC Modulation, AM Circuits, AM Demodulation Circuits, AM Transmitter, AM Receivers [Ref.3, Chapter 8 excluding 8.14]
SSB Modulation: SSB Principles, Balanced Modulators, SSB Generation, SSB Reception [Ref.3, Chapter 9, 9.1 to 9.5]
Frequency Modulation: FM, Sinusoidal FM, Spectrum for Sinusoidal FM, Average power in Sinusoidal FM, Non-sinusoidal FM, Deviation Ratio
Phase Modulation: Equivalence between FM and PM, Sinusoidal PM, Digital PM
FM and PM Circuits, FM Transmitters, FM and PM Detectors, Automatic Frequency Control and Amplitude Limiting, FM Broadcast Receivers, FM Stereo Receivers [Ref.3, Chapter 10, Excluding 10.17]

Pulse Code Modulation
Pulse Amplitude Modulation: Natural Sampling versus Flat-top sampling, Signal recovery through holding, Time Division Multiplexing of PAM Signals, Bandwidth requirement of a PAM Channel
Pulse Code Modulation: Quantization, Signal Compression and Expansion, PCM Receiver, Multiplexing PCM Signals, DPCM, Delta Modulation [Ref. 1, Chapter 5 and Ref. 3, Chapter 11]
Digital Line Waveforms: Symbols, Binits, Bits and Bauds – Functional notation of pulses, Line Codes and Waveforms, Spectra of Digital Line waveforms, M-ary Encoding, Inter Symbol Interference – Pulse Shaping

[Ref. 1, Chapter 5 and Ref. 3, Chapter 3]

Digital Communications
Base band transmission: Synchronization, Asynchronous transmission, Probability of Bit Error in Base band transmission, Matched Filter Concepts, Optimal Terminal Filtering, Bit timing recovery, eye diagrams [Ref. 3, Chapter 12]
Digital Modulation Systems: Binary Phase Shift Keying, Differential Phase Shift Keying, Quadrature Phase Shift Keying, M-ary PSK, QASK, Binary Frequency Shift Keying, M-ary FSK, Coherent Reception of Carrier Modulated Digital Transmission by Correlation Techniques, Use of signal space to calculate error probability for various carrier modulation schemes, Bit by Bit Encoding versus Symbol-by-Symbol encoding, Relation between Bit Error rate and Symbol Error rate, Introduction to error control coding [Ref 1, Chapter 6 and Chapter 11]

References:

1. Taub& Schilling, 'Principles of Communication Systems' 2nd edition, McGraw-Hill International Edition,
2. Simon Haykin, `Communication Systems', 4th Edition,Wiley Student Edition,2004.
3. Dennis Roddy & John Coolen,, 'Electronic Communication',4th Edition, Pearson, 2004.
4. Rodger E. Ziemer& William H. Tranter, 'Principles of Communications', Wiley, 2014.

EE3012E INSTRUMENTATION SYSTEMS

Pre-requisites: NIL

L	T	P	O	C
2	1	2	4	3

Total Sessions: 39

Course Outcomes:

CO1: Describe the working of active and passive sensors /Transducers for the measurement of nonelectrical quantities.
CO2: Select sensors for measurement of nonelectrical quantities in process industries.
CO3: Devise an appropriate signal conditioning circuit for a measurement system.
CO4: Design industrial techniques such as programmable logic controllers and automated assembly systems.

Introduction to Instrumentation Systems
Introduction to sensors /transducers, Primary and secondary transducers, static and dynamic characteristics, Calibration & errors, Classification of transducers: Passive Transducers – resistive, Inductive and capacitive Transducers, Active Transducers – Thermoelectric, piezoelectric, Magnetostrictive, Hall Effect, Electromechanical, ElectroChemical- Digital Transducer, Feedback Transducers Systems. Recent Developments in sensor technology - Smart Sensors-Micro sensors, IR Radiation Sensors, Ultrasonic Sensors, Fibre Optic Sensors.

Experiment:

11. Calibration of Pressure measurement systems.
12. Real-time implementation of a simple measurement system using a transducer.

Measurement of non-electrical quantities
Measurement of Temperature – RTD, Thermistor, Thermocouple, Pressure – Diaphragm, Bellow, Capsule, Bourdon tube, Differential Pressure Transmitter (DPT), Flow- Orifice meter, Rotameter, Electromagnetic flow meter, Liquid level – Capacitive Level sensor, Force-Strain Gauge, Cantilever load cell, Torque-Elastic Torque Sensor, Density-Oscillating Coriolis Densitometer, Viscosity – Vibrating Reed Viscometer, and Displacement measurement- LVDT, RVDT.
Experiment:

13. Demonstration of level, flow, and temperature sensors in a MIMO feedback system.

Signal conditioning and signal processing circuits
Signal conditioners – Design and implementation of operational amplifiers based circuits of Difference or Balanced Amplifiers, instrumentation amplifiers, isolation amplifiers, charge/ power Amplifiers, voltage–current converters, voltage-frequency converters, analog multiplexers, and de-multiplexers for instruments in practical applications. Fundamentals of 4-20 mA current loops and 3-15psi pressure loops, Regulators, and power supplies for industrial instrumentation – linear series voltage regulators – linear shunt voltage regulators – integrated circuit voltage regulators.
Experiment:

14. Design and implementation of operational amplifier-based signal conditioning circuit.
15. Implementation of the designed signal conditioning circuits for a measurement application.

PLC & DCS
Programmable Logic Controllers: Introduction to PLC Programming- Basic Structure. PLC Programming: Ladder Diagram –Ladder diagram circuits. PLC Selection: I/O quantity and Type, Memory size and type.

Distributed Control System: Introduction, Overview of Distributed Control System, DCS Integration with PLCs and Computers, Features of DCS, Advantages of DCS.

Experiment:

16. PLC programming and implementation for industrial automation (Lift control, Single Tank system).

References:

1. Doebelin E. O. and Manik D. N., “Measurement Systems”, 6th Ed., 2017 Tata McGraw-Hill Publishing Company Limited.
2. Johnson C. D., “Process Control Instrumentation Technology”, 8th Edition, 2014 Ed., Prentice Hall of India Private Limited.
3. Cooper W. D. and Helfrick A. D, “Modern Electronic Instrumentation and Measurement Techniques”, Pearson Education. 2016
4. E.W. Golding and F.C.Widdis, “ Electrical measurements and measuring Instruments” ,2011, Reem Publications Pvt, Ltd.
5. Oliver B. M. and Cage J. M., “Electronic Measurement and Instrumentation”, McGraw-Hill International Book Company. 2017
6. Bela G. Liptak, Instrument Engineer’s Handbook – Process Control, Chilton Company, 4th Edition, 2006.
7. Andrew Williams, “Applied instrumentation in the process industries”,3rd Edition, 2007,Vol. 1 & 3, Gulf publishing company.
8. Tattamangalam R. Padmanabhan “Industrial Instrumentation Principles and Design” springer, May 2000.

EE3093E ELECTRICAL ENGINEERING DRAWING

Pre-requisites: Nil

L	T	P	O	C

1	0	2	3	2

Total Sessions: 13 (L)+ 26 (P)

Course Outcomes:

CO1: Draw different types of AC and DC armature windings
CO2: Visualize and draw the sectional plan and elevation of transformers
CO3: Analyse and draw the sectional elevation and end view of different type of DC machines and AC machines
CO4: Prepare the layout of outdoor and indoor substations
CO5: Use CAD tool for drawing electrical machines and electrical systems

Winding diagram

1. Simplex lap/ wave DC armature windings with end connections, indicating the brush positions with equalizer rings/ dummy coils.
2. Simplex lap/ wave, integral/ fractional slot, double layer three phase AC armature windings with full pitched/ short chorded coils.

Transformers
1. Sectional plan and elevation of a transformer limb with windings.
2. Sectional plan and elevation of the core assembly of a power transformer.
3. Sectional plan and elevation of a distribution transformer tank with its accessories.
4. Sketches of capacitor and oil filled type transformer bushings.

Rotating Machines
DC Machines:
1. Half sectional Elevation and side view of armature with commutator of a DC machine, including the connections.
2. Preparation of Sectional Elevation and side view of yoke and pole assembly with main field winding and interpole windings of a DC machine.
3. Preparation of Half Sectional Elevation of a DC machine with field, armature and commutator including connections
Alternators:
1. Sketches of the methods of pole fixing and slot details of turbo & water wheel alternators.
2. Sectional Elevation and side view of water wheel rotor assembly with winding.
3. Sectional Elevation and side view of salient pole alternator.
4. Sectional Elevation and side view of turbo alternator.
Induction Motors:
1. Preparation of Half Sectional elevation of slip ring induction motor with slip rings and brushes
2. Half sectional front and side elevation of squirrel cage induction motor.

Substations
Preparation of the following substation drawings and layouts
1. Layouts and single line diagrams of 3Φ, 11 kV HT outdoor and indoor substations.
2. Layout of a 3Φ, 220kV outdoor substation with duplicate bus bar/ tie bar, all accessories and switchgears.
3. Layout of a captive power substation.

Familiarization of CAD
1. Introduction to AutoCAD. Preparation of simple 2D AutoCAD drawings using the commands/tools of AutoCAD (Draw, Edit, View, Modify, dimension style, plotting, object and layer selection).
2. Drawing of Electrical symbols and introduction to symbol libraries and icons of Electrical CAD.
3. Half Sectional view of a DC machine with field, armature and commutator including connections.
4. Single line diagram of a distribution center.

References:

1. Clayton & Hancock, Performance and Design of DC Machines, ELBS, 1992.
2. Say M.G, Performance and Design of AC machines, Pitman, ELBS, 1991.

3. A.K. Sawhney, Electrical Machine Design, Dhanpat Rai, New Delhi, 1991.
4. Narang K.L., A Text Book of Electrical Engineering Drawing, Tech India Publications, 2016.
5. Bhattacharya S.K, Electrical Engineering Drawing, 2nd ed., Wiley Eastern., 2009

EE3094E Project

Pre-requisites: Nil

L	T	P	O	C
0	0	0	9	3

Total Lecture Sessions: Nil

Course Outcomes:

CO1: Identify a topic of interest relevant to industry or society in the field of Electrical Engineering or interdisciplinary field
CO2: Develop the skills of independent and collaborative learning
CO3: Formulate and develop a design proposal and to effectively communicate the same and complete the preliminary work by undertaking literature survey, case studies, data collection and feasibility studies
CO4: Design or model or algorithm for the selected idea/product through simulated or theoretical and experimental approach.
CO5: Write good technical report and make oral presentation of the work carried out

The project work will be of a design and/or experimental approach in the electrical engineering discipline or interdisciplinary field. An individual student or group of students from electrical engineering department or other department(s) of the institute can do project work under a supervisor, towards the innovative idea/social/product development. In case of interdisciplinary project, the faculty member(s) from the concerned department(s) are also the supervisor(s) for the students. A faculty coordinator will coordinate the project work of all students and will decide the maximum number of students in a project group.

The assessment of the project will be done at the end of the semester by a project review committee consisting of three or four faculty members from the concerned field. After completing the work to the satisfaction of the supervisor(s), the project report will have to be submitted by the student(s) to the project review committee. The project supervisor(s) and project review committee will award the grades to the individual student based on the performance and contribution by an individual.

EE3095E POWER SYSTEMS LAB

Pre-requisites: NIL

L	T	P	O	C
0	0	2	1	1

Total practical Sessions: 26

Course Outcomes:

CO1: Develop computer programs for power system studies.
CO2: Determine the sequence components of unbalanced voltages and fault currents of Power system elements
CO3: Select appropriate relay settings for various relays
CO4: Analyse various power system events using dedicated power system toolboxes
CO5: Prepare laboratory reports that clearly communicate experimental information in a logical and scientific manner.

List of Experiments:

1. Formation of YBUS using bus incidence matrix from system data (using MATLAB)
2. Modelling accuracy studies of transmission line models (using MATLAB)
3. Calculation of Bus voltages using Gauss-Siedel Method (using MATLAB)
4. Calculation of Jacobian and Bus voltages using NR method (using MATLAB)
5. Travelling wave characteristics of transmission lines for different types of terminations using PSCAD.
6. Design and simulation of automatic load frequency control for a two-area power system using MATLAB/SIMULINK
7. Short circuit analysis on a power system using PSCAD software
8. Load flow analysis on power system using ETAP software

Experiments on relay setup

9. Testing of Electromechanical Over Current relay and plot the graph between Trip Time Vs Plug Setting Multiplier (PSM).
10. Testing and Study of operating characteristics of Differential relay
11. Determination of Sequence Reactance's and fault studies of an Alternator
12. Testing of Electromechanical Under Voltage Relay and plot the graph between Operating Time Vs percentage of plug Setting voltage
13. Testing and Study of operating characteristics of Digital relay
14. Testing and Study of operating characteristics of Earth fault relay

Note: Normally the practical classes are administered in two cycles. Depending on the availability of equipment and time, course coordinators may choose the experiments for each cycle.

References:

1. Stanley H. Horowitz, Arun G. Phadke, and Charles F. Henville. ‘Power System Relaying’, 5th Edition, John Wiley & Sons 2022
2. D N Vishwakarma, Badri Ram, and Soumya R Mohanty. ‘Power System Protection and Switchgear’, 3rd Edition. McGraw Hill, 2022
3. Elgerd.O.I, ‘Electric Energy System Theory – An Introduction’, Tata McGraw Hill, New Delhi, 2013
4. Allen J. Wood, Bruce Wollenberg and Gerald B. Sheble “Power System Generation, Operation and Control’, 3rd Edition John Wiley and Sons, 2013
5. W.D. Stevenson: Elements of Power system Analysis, McGraw Hill International Student 4th Edition 2015
6. John J.Grainger , W.D. Stevenson: Power System Analysis, McGrawHill International (Indian Edition) 2017.
7. D.P. Kothari and I.J. Nagrath, Power System Engineering, 3rd Edition Tata McGraw-Hill Pub. Co., New

Delhi, 2019.

EE3096E CONTROL SYSTEMS LAB

Pre-requisites: NIL

L	T	P	O	C
0	0	2	1	1

Total Practical Sessions: 26

Course Outcomes:

CO1: Use laboratory techniques, tools, and practices of control engineering

CO2: Design and implement control systems for single-input single-output linear time-invariant systems and nonlinear systems

CO3: Report concisely the results of the work in the laboratory accurately in appropriate detail.

CO4: Work in a team and communicate effectively to perform the design and implementation of control schemes for various processes

List of Experiments:

1. Determine the transfer function of the given armature controlled and field controlled DC Motor
2. Determine the transfer function and obtain the load characteristics of the given amplidyne
3. Set up a closed loop position control system and study its performance using the given DC modular servo system
4. Design Lead, Lag and Lead-Lag compensators and obtain the characteristics by experiment and simulation
5. Set up a closed loop voltage regulation system for a separately excited dc generator using the given amplidyne and obtain its characteristics
6. Model the given Inverted pendulum system and study its closed loop performance
7. Model the given twin rotor MIMO system (TRMS) and study its response and control
8. Study of the given Level Process Control Station with different control schemes
9. Ladder Programming and PLC based process control
10. Dynamic System Simulation and Control
11. Real time control using dSpace
12. Familiarize the kinematics of the given 6 DoF robotic manipulator

References:

1. Katsuhiko Ogata, Modern Control Engineering, 5th edition, Pearson Prentice Hall, 2015.
2. I J Nagrath and M Gopal, Control Systems Engineering, 7rd ed., Tata McGraw Hill, 2021.
3. M. Gopal, Digital Control and State Variable Methods: Conventional and Neural-fuzzy Control Systems, Tata McGraw Hill, 2003.
4. M. Gopal, Control Systems, 4th ed., Tata McGraw-Hill, 2012.
5. K. P. Mohandas, Modern Control Engineering, Sanguine Pearson, Revised Edition, 2010.
6. G. C. Goodwin, S. F. Graebe and M. E. Salgado, Control System Design, Prentice Hall India, 2003.
7. J. J. D’Azzo, C. H. Houpis, S. N. Sheldon, Linear Control System Analysis & Design with MATLAB, 6th ed., CRC Press, 2013

Semester-VII

EE4091E Summer Internship

Pre-requisites: NIL

L	T	P	O	C
0	0	0	6	2

Total Sessions: Nil

Course Outcomes:

CO1 : Enhancement of employability through exposure to Industrial Environment & Professional Work Culture.
CO2 : Enhancement of employability through improvement in inter-personal skills in professional domain through interaction with mentor and industry personnel at various levels.
CO3 : Learn to apply engineering principles in a practical context through tasks assigned during internship.
CO4 : Learn how economic, market, environmental and ethical considerations affect the technical solution for a practical engineering problem through interaction with experienced industry professionals.

- Internship should be carried out during the Summer Vacation immediately after 6th Semester and should be of a minimum duration of 45 days. The evaluation of performance in this course will be done in the first week after commencement of 7th Semester. Student has to turn in a report in the beginning of 7th Semester, containing tasks assigned to him during the internship, record of work carried out during the internship, record of attainment of deliverables if any, learning attained by going through the internship etc., duly certified by the Mentor from the Industry/Institution where the Internship was carried out.
- Internship may be carried out , without limitation, at any (i) Industry involving generation/transmission/distribution/utilization of electrical energy at a captive scale or distributed scale (ii) Electronics Manufacturing Industries (iii) Software / IT Service / Fintech Industries (iv) Agri/Biotech Firms (v) Reputed Research/Academic Institutions in India or abroad (vi) CFTIs other than NIT Calicut (vii) Startups/Incubatee Companies under TBI NITC or similar reputed agencies in the country etc.
- Student/s may be allowed to carry out internship at various departments and schools at NIT Calicut itself under special conditions which include, but not limited to, requirement for such internship candidates as reported by Coordinators of various sponsored & consultancy projects received in NITC, requirement for such internship candidates in connection with preparation of academic resources as reported by Course Instructors, , requirement for such internship candidates as reported by Coordinators of various Research activities taking place in NITC etc. HOD of the Department will decide whether a student or group of students can be offered internship within NIT Calicut on a case by case basis, based on the Proposal (duly approved by the prospective mentor from NIT Calicut) submitted by the student or student group.
- Internship can involve, without limitation, one or a combination of following activities.
  (a) Carry out a short design/construction/testing project under mentorship from concerned Industry/Institute/Establishment on an individual basis or group basis.
  (b) Carry out short Software project in Engg/Educational/Fintech area under the mentorship from concerned Industry/Institute/Establishment on an individual basis or group basis.
  (c) Make a thorough study of products and processes in the concerned Industry.
  (d) Make a thorough study of maintenance activities, maintenance scheduling, preventive maintenance activities and inventory for maintenance activities in the concerned Industry.
  (e) Collaborate in an ongoing developmental project (hardware or software) under mentorship from concerned Industry/Institute/Establishment on an individual basis or group basis.
  (f) Carry out simulation tasks to assist in ongoing R & D projects under mentorship from concerned Industry/Institute/Establishment on an individual basis or group basis.
  (g) Acquire proficiency in using specialized test equipment in Electrical / Electronic / Industrial Instrumentation / Biomedical/ Power Plant areas under mentorship from concerned Industry/Institute/Establishment on an individual basis or group basis.
  (h) Develop expertise in using special purpose simulation platforms used in design and design verification of Engineering Systems under mentorship from concerned Industry/Institute/Establishment on an individual basis or group basis.

EE4092E Project

Pre-requisites: Nil

L	T	P	O	C
0	0	0	9	3

Total Lecture Sessions: Nil

Course Outcomes:

CO1: Identify a topic of interest relevant to industry or society in the field of Electrical Engineering or interdisciplinary field
CO2: Develop the skills of independent and collaborative learning
CO3: Formulate and develop a design proposal and to effectively communicate the same and complete the preliminary work by undertaking literature survey, case studies, data collection and feasibility studies
CO4: Design or model or algorithm for the selected idea/product through simulated or theoretical and experimental approach.
CO5: Write good technical report and make oral presentation of the work carried out

EE4092E Project should be carried out at NIT Calicut. The EE4092E Project may also be a continuation of EE3094E Project in the sixth semester. The EE4092E Project can be done by an individual and / or by a group of students from electrical engineering department or other department(s) of the institute. The type of the project can be analytical / simulation/ design or/and fabrication related to Electrical Engineering or interdisciplinary field. A faculty coordinator will coordinate the project work of all students and will decide the maximum number of students in a project group.

Evaluation will be done by a project review committee consisting of the concerned supervisor(s) and two/three faculty members in the concerned area of the project nominated by the HOD. The faculty coordinator of the project will be a member of the evaluation committee for all the projects. The mode of presentation, submission of the report, method of evaluation, award of grades etc will be decided by the project review committee. The students shall submit both soft and hard copies (required number of copies) of project report in the prescribed format to the department and library after incorporating all the corrections and changes suggested by the project review committee.

Semester-VIII

EE4093E Project

Pre-requisites: Nil

L	T	P	O	C
0	0	0	9	3

Total Lecture Sessions: Nil

Course Outcomes:

CO1: Identify a topic of interest relevant to industry or society in the field of Electrical Engineering or interdisciplinary field
CO2: Develop the skills of independent and collaborative learning
CO3: Formulate and develop a design proposal and to effectively communicate the same and complete the preliminary work by undertaking literature survey, case studies, data collection and feasibility studies
CO4: Design or model or algorithm for the selected idea/product through simulated or theoretical and experimental approach.
CO5: Write good technical report and make oral presentation of the work carried out

EE4093E Project should be carried out at NIT Calicut. The EE4093E Project may also be a continuation of E4092E Project in the seventh semester. The EE4093E Project can be done by an individual and / or by a group of students from electrical engineering department or other department(s) of the institute. The type of the project can be analytical / simulation/ design or/and fabrication related to Electrical Engineering or interdisciplinary field. A faculty coordinator will coordinate the project work of all students and will decide the maximum number of students in a project group.

Evaluation will be done by a project review committee consisting of the concerned supervisor(s) and two/three faculty members in the concerned area of the project nominated by the HOD. The faculty coordinator of the project will be a member of the evaluation committee for all the projects. The mode of presentation, submission of the report, method of evaluation, award of grades etc will be decided by the project review committee. The students shall submit both soft and hard copies (required number of copies) of project report in the prescribed format to the department and library after incorporating all the corrections and changes suggested by the project review committee.

EE4094E Internship

Pre-requisites: NIL

L	T	P	O	C
0	0	0	18	6

Total Sessions: Nil

Course Outcomes:

CO1 : Enhancement of employability through exposure to Industrial Environment & Professional Work Culture.
CO2 : Enhancement of employability through improvement in inter-personal skills in professional domain through interaction with mentor and industry personnel at various levels.
CO3 : Learn to apply engineering principles in a practical context through tasks assigned during internship.
CO4 : Learn how economic, market, environmental and ethical considerations affect the technical solution for a practical engineering problem through interaction with experienced industry professionals.

- Internship should be carried out during the Eight Semester immediately after 7^{th} Semester and should be of a minimum duration of 4 months from date of eight semester registration.
- Evaluation will be done by an internship review committee nominated by the HOD. The faculty coordinator of the internship will be a member of the evaluation committee for all the projects. The mode of presentation, submission of the report, method of evaluation, award of grades etc will be decided by the internship review committee. The students shall submit both soft and hard copies (required number of copies) of project report in the prescribed format to the department and library after incorporating all the corrections and changes suggested by the internship review committee.
- Student has to submit a report, containing tasks assigned to him during the internship, record of work carried out during the internship, record of attainment of deliverables if any, learning attained by going through the internship etc., duly certified by the Mentor from the Industry/Institution where the Internship was carried out.
- Internship may be carried out, without limitation, at any (i) Industry involving generation/transmission/distribution/utilization of electrical energy at a captive scale or distributed scale (ii) Electronics Manufacturing Industries (iii) Software / IT Service / Fintech Industries (iv) Agri/Biotech Firms (v) Reputed Research/Academic Institutions in India or abroad (vi) CFTIs other than NIT Calicut (vii) Startups/Incubatee Companies under TBI NITC or similar reputed agencies in the country etc.
- Internship can involve, without limitation, one or a combination of following activities.
  (i) Carry out a short design/construction/testing project under mentorship from concerned Industry/Institute/Establishment on an individual basis or group basis.
  (j) Carry out short Software project in Engg/Educational/Fintech area under the mentorship from concerned Industry/Institute/Establishment on an individual basis or group basis.
  (k) Make a thorough study of products and processes in the concerned Industry.
  (l) Make a thorough study of maintenance activities, maintenance scheduling, preventive maintenance activities and inventory for maintenance activities in the concerned Industry.
  (m) Collaborate in an ongoing developmental project (hardware or software) under mentorship from concerned Industry/Institute/Establishment on an individual basis or group basis.
  (n) Carry out simulation tasks to assist in ongoing R & D projects under mentorship from concerned Industry/Institute/Establishment on an individual basis or group basis.
  (o) Acquire proficiency in using specialized test equipment in Electrical / Electronic / Industrial Instrumentation / Biomedical/ Power Plant areas under mentorship from concerned Industry/Institute/Establishment on an individual basis or group basis.
  (p) Develop expertise in using special purpose simulation platforms used in design and design verification of Engineering Systems under mentorship from concerned Industry/Institute/Establishment on an individual basis or group basis.

EE4095E Activity Credits

List of Electives

EE2021E PYTHON PROGRAMMING AND APPLICATIONS

Pre-requisites: NIL

L	T	P	O	C

3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: To become proficient in writing Python code

CO2: Knowledge of when to use specific data structures based on the problem requirements

CO3: Ability to design and implement algorithms for solving various types of problems

CO4: Debugging skills to identify and fix errors in code

CO5: Understanding the ethical considerations in software development, including privacy, security, and responsible data handling

Introduction to Python, Functions and Data structures
Basic syntax and data types - Variables and data manipulation - Input and output - Control structures (if statements, loops) - Functions and Modules- Defining and using functions, Scope and lifetime of variables, Importing and using modules - Lists, tuples, and dictionaries - Sets and frozen sets - Strings and string manipulation - Lists comprehensions and generators

Object-Oriented Programming in Python and Recursive functions
Classes and objects - Inheritance and polymorphism - Encapsulation and abstraction - Understanding recursion-Recursive functions – Memoization - Stacks and queues - Linked lists - Trees (binary trees, binary search trees) - Graphs (representation and basic algorithms)

Algorithms and analysis
Searching algorithms - linear search, binary search - Sorting algorithms - bubble sort, selection sort, insertion sort - Time complexity analysis (big O notation) - Hashing and hash tables - Divide and conquer algorithms - Greedy algorithms - Dynamic programming - Algorithm Analysis - Asymptotic analysis (best-case, worst-case, and average-case analysis) - Amortized analysis - Space complexity analysis

Advanced data structures and advanced algorithms
Priority queues and heaps - Balanced binary search trees (AVL trees, Red-Black trees) - Hashing techniques (open addressing, chaining) - Breadth-First Search (BFS) - Depth-First Search (DFS) - Shortest path algorithms (Dijkstra's, Bellman-Ford) - Minimum spanning tree (Prim's, Kruskal's) - Computational geometry - Network flows - Approximation algorithms

References:

5. M. T. Goodrich, R. Tamassia, and M. H. Goldwasser, *Data Structures and Algorithms in Python*, Wiley, 2013.
6. T. H. Cormen, C. E. Leiserson, R. L. Rivest, and C. Stein, *Introduction to Algorithms*, The MIT Press, 2009.
7. Brad Miller and David Ranum, *Problem Solving with Algorithms and Data Structures using Python*, 3rd ed. Franklin, Beedle & Associates, Inc., 2013.

EE2022E INTRODUCTION TO C PROGRAMMING

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Ability to write algorithms for problem

CO2: Knowledge of the syntax and semantics of C programming language

CO3: Ability to code a given logic in C language

CO4: Knowledge in using C language for solving problems

Introduction to computers

Introduction to computers - Types of programming languages- Developing a program – Algorithms Characteristics- Flow Charts- Principles of structured programming- Sequential selecting structures- Repetitive Structures-Bounded, Unbounded and Infinite iterations.

Introduction to C- C character set

Introduction to C- C character set- Identifiers and Keywords- Data types- Constants- Variables- Declarations Expressions- Statements- Symbolic Constants- Operators- Library Functions- Data input and output: Single character input and output- Entering input data- Writing output data- gets and puts functions - Control Statements- Branching: if-else-looping: while- do-while-for; Nested control Structures- switch statements Break statements- Continue Statements- Comma operator- goto statements.

Modular Programming

Modular Programming- Functions and Procedures - Examples- Parameters passing methods - Arrays- Defining an array- Processing an array- Multi dimensional arrays- Pointers- Variables definitions and initializations Pointer operators- Pointer expressions and arithmetic- Pointers and one-dimensional arrays - String operations.

Functions

Functions- Defining function- Accessing a function- Function prototypes- Passing arguments to a functions Passing arrays to a function- Passing Pointers to function- Recursion – Dynamic memory allocation - malloc, calloc, realloc – Structures – Declaration – Structures and Functions – Arrays of Structures – Pointers to structures – Typedef - Unions – Bit-fields.

Files – Input / Output using files – fread, fwrite, fprintf, fscanf – Formatted input – File access - argc, argv.

References:

1. Byron Gottfried, *Programming with C*, 3rd Edition, Tata McGraw Hill Education, 2010.
2. R.G. Dromey, *How to solve it by Computers?* Prentice Hall, 2011.
3. Brian W Kernighan and Dennis Ritchie, *The C Programming language*, 2nd Edition, Prentice Hall, 1988.
4. J.R.Hanly and E.B. Koffmann, *Problem Solving and Program design in C*, 6th Edition, Pearson Education, 2009.
5. Paul Deital and Harvey Deital, C How to Program? 7th Edition, Prentice Hall, 2012.
6. YashvantKanetkar, Let Us C, 12th Edition, BPB Publications, 2012.

EE3021E DIGITAL CONTROL SYSTEMS

L	T	P	O	C
3	0	0	6	3

Total Sessions: 39

Course Outcomes:

CO1: Apply the basic principles and modeling of digital control system in transfer function and state-space domain.
CO2: Analyze different aspect of time response such as steady state analysis, transient response analysis, disturbance rejection, robustness and sensitivity.
CO3: Apply the analysis techniques based on Root locus, Bode and Nyquist plots, Jury stability criteria, Routh stability criteria and Bilinear transformation.
CO4: Design various digital controllers using time domain and frequency domain methods.

Fundamentals and Modelling
[Revise the classical methods of linear continuous-time control systems-No class time allotted]
Basic digital control system- Examples - D/A and A/D conversion, quantization and delay effects, principles of discretization, mathematical model, Data reconstruction-ZOH and FOH- choice of sampling rate--Mapping between s-domain and z-domain-Pulse transfer function- Different configurations for the design- Modified z-transform- Multi-rate discrete data systems. Sampled signal flow graph

Time and Frequency domain Analysis
Time responses of discrete data systems- Correlation between time response and root locations in the z plane - Steady state performance- Disturbance Rejection- Robustness and Sensitivity -Jury's stability test – Routh stability criterion on the r-plane -Root locus- Polar plots-Nyquist stability criterion- Bode plot- Bilinear transformation method.

Controller Design and Realization
Cascade compensators using Root Locus- Design of PID controllers by using bilinear transformation- Digital controller design using bilinear transformation- Dead-beat response design- Deadbeat controller without and with prescribed manipulated variable-Choice of sample time for deadbeat controller-Realization of Digital controllers-Computer based simulation.

State-Space Analysis
State variable model of discrete data systems with S/H devices- State transition equations- state diagrams Transfer function- Transformation to Jordan canonical form and phase variable form- Computation of state transition matrix using Cayley-Hamilton theorem and z-transform method- Response between sampling instants, Controllability, Observability, stabilizability and reachability- Loss of controllability and observability due to sampling- Pole placement design using state feedback for SISO systems- Computer based simulation.

References:

1. M.Gopal, *Digital control and State Variable methods*, 4th ed, Tata McGraw Hill, 2017
2. Benjamin C Kuo, *Digital Control Systems*, 2nd edition, Oxford University Press, 1995.
3. Constantine H. Houpis and Gary B. Lamont, *Digital control systems: Theory, hardware, software,* Mcgraw-Hill Book Company, 2nd ed., 1992.
4. R.Isermann, *Digital control systems, Volume 1: Fundamentals, Deterministic control*, Springer Verlag, 2nd revised ed., 1989.
5. R.G.Jacquot, *Modern digital control systems*, 2nd ed., Marcel Dekker, Inc., 1994.
6. Phillips, Nagle and Aranya Chakrabortty, Digital control system analysis and design, 4th ed, Pearson Prentice Hall, 2014.
7. G.F.Franklin, J.David Powell and M.Workman, *Digital Control of Dynamic Systems,* 3rd ed., Addison Wesley, 1997.

EE3022E ELECTRICAL MACHINE DESIGN

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Carry out preliminary design of dc machines for a given set of specifications
CO2: Carry out preliminary design calculation of Transformers.
CO3: Perform preliminary design of alternators for a given set of specifications.
CO4: Perform preliminary design of induction motors for a given set of specifications

DC Machines
Output equation-Torque Equation - main dimensions - choice of specific electric and magnetic loadings - choice of speed and number of poles - design of armature conductors, slots and winding - design of air-gap, field system, commutator, interpoles, compensating winding and brushes - Carter's coefficient - real and apparent flux density - design examples.

Transformers
Output equation - single phase and three phase power transformers - main dimensions - choice of specific electric and magnetic loadings - design of core, LV winding, HV winding, tank and cooling tubes - prediction of no load current, short circuit impact on windings, leakage reactance and equivalent circuit based on design data - design examples- Design of high frequency transformer for power electronics applications.

Synchronous Machines
Output equation - salient pole and turbo alternators - main dimensions - choice of specific electric and magnetic loadings - choice of speed and number of poles - design of armature conductors, slots and winding - design of air-gap, field system and damper winding - prediction of open circuit characteristics and regulation of the alternator based on design data - design examples. Design of PMSM motor

Induction Machines
Output equation - main dimensions - choice of specific electric and magnetic loadings - design of stator and rotor windings, stator and rotor slots and air-gap of slip ring and squirrel cage motors - calculation of rotor bar and end ring currents in cage rotor - calculation of equivalent circuit parameters and prediction of magnetizing current based on design data - design examples.

References:

1. Clayton A E & Hancock N N, Performance and Design of DC Machines, ELBS,1971.
2. Say M G, The Performance and Design of AC Machines, CBS, 1983.
3. Sawhney A K, A Course in Electrical Machine Design, Dhanpat Rai & Co., 2016.
4. Permanent Magnet Synchronous Motor Drives: Analysis, Modeling and Control January 2009 by Enamul Md Haque, VDM Verlag (1 January 2009)
5. Kenjo T and Nagamoris "Permant Magnet & brushless DC motor" Clarendon press, Oxford, 1989
6. COLONEL WM. T. MCLYMAN, TRANSFORMER AND INDUCTOR DESIGN HANDBOOK Third Edition, Revised and Expanded, Kg Magnetics, Inc.Idyllwild, California, U.S.A. Marcel Dekker, Inc. All Rights Reserved.

EE3023E DYNAMIC ANALYSIS OF ELECTRICAL MACHINES

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Develop analytical skill for analyzing simple electromechanical systems with focus on electromechanical energy conversion.
CO2: Develop analytical skills for modeling commonly used commutator machines and for carrying out large signal and small signal analysis on such machines.
CO3: Develop competence in preparing Induction Motor equations in various commonly used reference frames in current formulation and flux linkage formulation.
CO4: Develop competence in preparing Wound Field and PM Synchronous Machine equations in Park's reference frame in current formulation and flux linkage formulation.
CO5: Develop competence in preparing state space models for Induction and Synchronous machines for large signal and small signal studies and prepare simulation diagrams for that purpose.
CO6: Develop competence in preparing state space models for Interconnected machines for large signal and small signal studies and prepare simulation diagrams for that purpose.

Primitive four winding commutator machine analysis

Electro dynamical Equations and their Solution. A spring and Plunger System- Rotational Motion System, Mutually Coupled Coils. Solution of Electro-dynamical Equations by Euler's method and Runge-Kutta method. Linearization of the Dynamic Equations and Small Signal Stability. Differential Equations of a smooth air-gap two winding machine. Conditions for Conversion of Average Power in such a Machine. A two phase machine with current excitation - Interpretation of the Average Power Conversion Conditions in terms of air-gap Magnetic Fields. The Primitive 4 Winding Commutator Machine- The Brush Axis and its Significance. Self and Mutually induced voltages in the stationary and commutator windings. Speed e.m.f induced in Commutator Winding. Rotational Inductance Coefficients. Sign of Speed e.m.f terms in the Voltage Equation. The Complete Voltage Equation of Primitive 4 Winding Commutator Machine. The Torque Equation. Analysis of Simple DC Machines using the Primitive Machine Equations.

Modelling of three phase Induction machines

The Three Phase Induction Motor. Equivalent Two Phase Machine by m.m.f equivalence. Equivalent two phase machine currents from three phase machine currents. Power Invariant Phase Transformation. Voltage Transformation. Voltage and Torque Equations of the Equivalent Two Phase Machine. Commutator Transformation and its interpretation. Transformed Equations. Different Reference Frames for Induction Motor Analysis. Nonlinearities in Machine Equations. Equations under Steady State - Solution of Large Signal Transients in an Induction Machine. Linearized Equations of Induction Machine. Small Signal Stability. Eigen Values. Transfer Function Formulation. Simulation of variable frequency drive (applying DQ transformation) using MATLAB.

Modelling of three phase Synchronous machines

The Three Phase Salient Pole Synchronous Machine. Voltage and Torque Equations in stator, rotor and air-gap field reference frames. Commutator Transformation and Transformed Equations. Parks Transformation. Suitability of Reference Frame Vs kind of Analysis to be carried out. Steady State Analysis. Large Signal Transient Analysis. Linearization and Eigen Value Analysis. General Equations for Small Oscillations. Small Oscillation Equations in State Variable form, Damping and Synchronizing Torques in Small Oscillation Stability Analysis .Application of Small Oscillation Models in Power System Dynamics.

Dynamic Analysis of Interconnected Machines

Machine Interconnection Matrices. Transformation of Voltage and Torque Equations using Interconnection Matrix. Large Signal Transient Analysis using Transformed Equations. Small Signal Model using Transformed Equations.

The DC Generator/DC Motor System. The Alternator /Synchronous Motor System.. Hunting Analysis of Interconnected Machines Selection of proper reference frames for individual machines in an Interconnected System.

References:

1. P.C. Kraus O. Wasynczuk and S.D. Sudhoff, *Analysis of Electric Machinery and Drive Systems*, Wiley Interscience, 2002
2. Jones C V, The Unified Theory of Electrical Machines, Butterworth, London,1967.
3. Sengupta D P & J.B. Lynn, *Electrical Machine Dynamics*, The Macmillan Press Ltd, 1980.
4. Woodson & Melcher, *Electromechanical Dynamics*, Vol. 1, John Wiley & Sons, 1968.
5. Ned Mohan, *Advanced Electric Drives: Analysis, Control, and Modeling Using MATLAB / Simulink*, Wiley, 2014.

EE3024 EELECTRICAL SYSTEM DESIGN FOR BUILDINGS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture sessions:39

Course Outcomes:

CO1:Design,estimateandevaluate the cost of electrical installations in residential, commercial, recreational buildings and small industries.
CO2:Design illumination schemes for building interiors and exteriors
CO3:Design and estimate outdoor and indoor substations.
CO4: Design the earthing system for electrical installations.

Module1:
Electrical Installations: general requirements, design considerations, testing, estimating and costing-symbols,standards–NationalElectricalCode–designofpanelboards– service connections- design, estimation and costing of residential buildings, electrical layout of residential buildings using AutoCAD.

Module2:
Illumination schemes – types of light sources and lighting arrangements – energy efficiency in lamps and illumination–design of lighting for interior and exterior applications.

Module3:
Electrical system design, estimation and costing of commercial buildings, hospitals, school buildings, recreational and assembly buildings, cinema theatres, small industries, Design of electrical installations of high rise buildings: electrical aspects of lifts, escalators services, stand by generators.

Module4:
Design and estimation of outdoor and indoor Substations - Layouts and single line diagrams of outdoor and indoor substations in AutoCAD–Design of earthing system, earth mat, plate and pipe earthing–Safety of electrical installations–Lightning protection.

References:

1. K.B.Raina, S.K.Bhattacharya, *Electrical Design, Estimating and Costing*, New Age International(p) Ltd.Publishers,NewDelhi,2002.
2. Surjit Singh. *Electrical Estimating and Costing*, Dhanpat Rai&Co.,Delhi,2005.
3. ISI, *National Electrical Code*, Bureau of Indian Standard Publications.
4. G. Ramamurthy, *Hand book of Electrical Power Distribution*, Universities Press (India) Private Ltd., NewDelhi,2004.
5. N Alagappan, S Ekambaram, *Electrical estimating and Costing*, McGraw-Hill,1999.
6. Narang K.L., *A Text Book of Electrical Engineering Drawing*, Tech India Publications,1963
7. Er. V. K. Jain, Er. Amitabh Bajaj, *Design of Electrical Installations*, University Science Press.
8. *Code of practice for Electrical wiring installations*, (System voltage not exceeding 650 volts), Indian Standard Institution, IS: 732-1983.
9. Guide for Electrical layout in residential buildings, Indian Standard Institution, IS: 4648-1968.

EE3025E DIGITAL CMOS INTEGRATED CIRCUITS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Acquire basic knowledge on digital circuits using CMOS.
CO2: Develop design capability in Combinational logic circuits using CMOS.
CO3: Develop design capability in synchronous and asynchronous sequential CMOS circuits.
CO4: Develop capability to design state-of-the art of memory unit, PLL, DLL circuits.
CO5: Develop knowledge on design trade-offs in various digital CMOS circuits towards speed of operation and power consumption and power optimization design approach.
CO6: Develop knowledge in data paths in digital processor architectures.

Module 1:
The static behavior of CMOS inverter-evaluating the robustness of the CMOS inverter in terms of switching threshold, noise margins. The dynamic behavior of CMOS inverter- computing the capacitances, propagation delay-first order analysis, dynamic power consumption, energy and energy-delay. Analyzing power consumption using SPICE. Combinational logic Gates in static CMOS- Complementary CMOS, Ratioed logic, pass transistor logic, transmission logic. Dynamic CMOS logic design-basic principle, speed and power dissipation of dynamic logic, VTC, fan-in, fan-out , cascading dynamic logic gates.

Module 2:
Design of sequential logic circuits using CMOS — timing metrics for sequential circuits, classification of memory elements. Static latches and registers- bistability principle, multiplexer-based latches, master-slave edge-triggered register. Dynamic latches and register— dynamic transmission-gate edge-triggered registers, basic approaches-C2MOS approach, TSPCR approach. Pipelining - An approach to optimize sequential circuits, latch vs, register based pipelines, pipeline structures. Non-bistable sequential circuits-Schmitt trigger, monostable sequential circuits, astable circuits.

Module 3:
Timing issues in digital circuits — classification of timing in digital circuits, synchronous timing basics, sources of skew and jitter, clock distribution technique, latch based clocking. Self- timed logic-an asynchronous technique, completion signal generation, practical example of self timed logic. Clock synthesis and synchronization using phase-locked loop. Distributed clocking using DLLs. Synchronous vs. Asynchronous design.

Module 4:
Data paths in digital processor architectures- the adder- the binary adder- definitions, logic and design considerations, the multiplier-definitions, logic and design considerations, partial-product generation, accumulation, final addition, the shifter- barrel shifter, logarithmic shifter. Power and speed trade-offs in data path structures. Design time power reduction techniques, run-time power management, reducing the power in standby mode.

References:

1. E. Elmasry, ed., Digital MOS Integrated Circuits II, IEEE Press, 1992.
2. A. Kang and Leblebici, CMOS Digital Integrated Circuits, 2nd ed., McGraw-Hill, 1999.
3. M. Annaratone, Digital CMOS Circuit Design, Kluwer, 1986.
4. M. Shoji, High-Speed Digital Circuits, Addison-Wesley, 1996
5. A. Chandrakasan and R. Brodersen, Low-Power Digital CMOS Design, IEEE Press, 1998.
6. Rabaey, Digital Integrated Circuits- A design perspective, 2nd ed., Pearson Education, 2003

EE3026E ELECTRICAL ENGINEERING MATERIALS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total sessions: 39

Course Outcomes:

CO1: Identify the processes responsible for electrical and thermal conduction in metals.
CO2: Understand the processes responsible for magnetic properties and superconductivity.
CO3: Evaluate any material for engineering applications based on electrical and non-electrical properties.
CO4: Select passive components for applications associated with electrical and electronic systems

Conductors and Semiconductors

Brief of Atomic model, Different type of bonds, Classification of solids on the basis of energy gaps, Conducting materials, electrical conduction in metals on the basis of free electron theory-electrical and thermal conductivity, Wiedemann-Franz law, Thermo electric effect, Seeback effect, Peltier effect – factors affecting electrical conductivity of metals, low resistivity metals, high resistivity metals, Contact materials, Fuse materials, Filament materials, solder materials, brushes of electrical machines.

Semiconducting materials, fermi Energy level, Intrinsic semiconductors, Extrinsic semiconductors, Effect of temperature on semiconductor properties, Hall Effect, Drift and diffusion current, Einstein relation, Solar cells, LED, Semiconductor lasers.

Dielectrics and insulating materials

Dielectrics: Dielectric polarization under static fields, electronic, ionic and dipolar polarizations, behavior of dielectrics in alternating fields, complex dielectric constant, dissipation factor, Effect of temperature on dielectric constant, Electrostriction effect, Ferro and piezo electricity

Requirements of good insulating materials, mechanical strength, thermal properties, breakdown strength, Thermal classification of solid insulating materials, inorganic materials (mica, glass, porcelain, asbestos),organic materials (thermoplastic and thermosetting polymers, rubber, paper), resins and varnishes, liquid insulators(transformer oil),gaseous insulators (air, SF6, and hydrogen),ageing of insulators.

Magnetic materials and superconductors

Magnetic materials: Classification of magnetic materials, origin of permanent magnetic dipoles ferromagnetism, hysteresis curve, magnetic domain theory-reasons of permanent magnetization, hard and soft magnetic materials, magnetostriction magnetic materials used in electrical machines instruments and relays

Super conductors, effect of magnetic field, Meissner effect, type I and type II superconductors, London equations, applications of superconductors

Materials for Passive components and PCB

Materials for passive components, resistors, insulated moulded resistors, Cracked carbon resistors, alloy resistors, metallic oxide thin film resistors, High value resistors, wire wound resistors, non-linear resistors, varistors ,capacitors, mica- dielectric capacitors, glass-dielectric capacitors, plastic-dielectric capacitors etc inductors ,air cored coils ,cored coils-ferrite core-relays, Printed Circuit Boards, Types of PCB Laminates, Layout and design of PCB, PCB manufacturing processes

References:

1. K.M. Gupta and Nishu Gupta, *Advanved electrical and Electronic Materiials: Processes and Applications*, scrivenrr Publications, Wiley,2015

2. Indulkar C.S. and Thiruvengadam S, *An Introduction to Electrical Engineering Materials*, 6th ed., S. Chand & Co Pvt Ltd, 2011.
3. P.K. Palanisamy, *Solid State Physics*, Scitech Publications, Hyderabad, 2011.
4. A.J. Dekker, *Electrical Engineering Materials*, 1st ed., Prentice Hall of India, 1963.
5. Yu Koritsky, *Electrical Engineering Materials*., Moscow MIR, 1970.
6. Arumugam M., *Materials Science.*, Anuradha Publishers, 1990.
7. Kapoor P.L., *Electrical Engineering Materials*, Khanna Publications, 2014.
8. Hutchison T.S. and Baird D.C, *The Physics of Engineering Solids*, 2nd ed., John Wiley Publications, 1968.
9. S.O.Kasap, *Principles of Electrical engineering Materials and Devices*, Tata McGraw Hill. 2000
10. R.K. Rajput, *Electrical Engg. Materials*, 2nd ed., Laxmi Publications, 2015.
11. T. K. Basak, *Electrical Engineering Materials*, New age International, 2008.
12. Solymar, *Electrical Properties of Materials*, 9th ed., Oxford University Press, 2014.
13. I. P. Jones, *Material Science for Electrical and Electronic Engineering*, Oxford University Press, 2000.
14. TTTI Madras, *Electrical Engineering materials*, Tata McGraw Hill, 2004.

EE3027E DYNAMIC SYSTEM SIMULATION

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total sessions: 39

Course Outcomes:

CO1: Develop mathematical models of dynamic systems for digital computer simulation
CO2: Employ software tools for real-time simulations of dynamical systems
CO3: Simulate electrical machines, drives and controls using digital computer
CO4: Evaluate dynamical models for electric vehicles and robotic systems using simulation tools

Basics of System Simulation

Review of mathematical methods for computer based simulation of dynamic systems-numerical methods for solution of differential equations-numerical integration-matrix methods-random number generation random processes-stochastic processes-discrete time models-event driven systems-queues- effect of sampling time on proper results-connection between simulation time and real time-transient responses for first order systems, second order systems-continuous time and discrete time systems-simulation of feedback control systems.

System Simulation Software

Common simulation environments-text based programming and block set based programming- - exercises for simulation of first order and second order systems using popular programming languages-familiarization of custom software tools – MATLAB, PSCAD, ROS etc. - Introduction to hardware in the loop (HIL) simulation – dSpace, Opal-RT, RTDS etc.

Simulation of Electrical machines and Electric Vehicles

Modeling and simulation of electrical machines- Transfer function modeling-for DC machines and AC machines-Modeling of special machines-generalized machine modeling-transformations used in generalized modeling-simulation of various machines for various working conditions. Simulation of multimachine dynamics.

Modeling and simulation of power converters and drives-Harmonic analysis of outputs of power converters-determination of conversion efficiency – modelling of battery controlled electric vehicles – vehicle dynamics modelling- analysis

Simulation of Robotic Systems

Fundamentals of Robotics – Mathematical modelling - Simulation of Robotic systems – Robot Operating Systems (ROS) – Nodes - Simulation of ground vehicles – Simulation of Aerial Vehicles -simulation of underwater vehicles

References:

1. Karnopp, Dean C, Donald L. Margolis, Ronald C. Rosenberg, System Dynamics: Modeling, Simulation, and Control of Mechatronic Systems, John Wiley & Sons, 2012.
2. Fabien, Biran, Analytical System Dynamics: Modeling and Simulation, Springer, 2009.
3. Argyris, J., Faust, G., Haase, M, Friedrich, R, An Exploration of Dynamical Systems and Chaos, Springer 2015.
4. Chee-MunOng, Dynamic Simulations of Electric Machinery: Using MATLAB/SIMULINK, Prentice Hall, 1998.
5. Quigley, Morgan, Brian Gerkey, and William D. Smart. Programming Robots with ROS: a practical introduction to the Robot Operating System. " O'Reilly Media, Inc.", 2015.

EE3028E NETWORK ANALYSIS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze linear electrical circuits using graph theory
CO2: Apply computer-based methods for solutions for simple networks using graph theory
CO3: Analyze two-port passive networks and derive network parameters
CO4: Evaluate parameters for passive two port filters using given specifications
CO5: Synthesize dissipative and non-dissipative electrical networks

Linear Graph Theory & Networks
LinearOrientedGraphs-incidencematrix–Kirchoff'sLawsinincidencematrixform–nodalanalysis(withindependentanddependentsources)–Circuitmatrixoflinearorientedgraph–Kirchoff'slawsinfundamental circuit matrix form - Loop analysis of networks (with independent and dependent sources) –Planar graphs – Mesh analysis- Duality – Cut set matrix - Fundamental cut set matrix – Relation between circuit, cut set and incidence matrices – Kirchoff's laws in fundamental cut set form – Node pair analysis –Analysis using generalized branch model (node, loop and node pair analysis) – Tellegen's theorem for lumped parameter network in topological form.

Two Port Networks & Passive Filters
Modeling Two-port networks-examples-amplifiers, transmission lines, passive filters-describing equationsandparametersetsfortwo-portnetworks-equivalentcircuitforatwoportnetwork-inter-relationshipbetween parameters- driving point and transfer impedance- determination of parameters for T and Phinetworks-reciprocityandsymmetry-characteristicimpedance-propagationconstant—derivationofcharacteristic impedance and propagation constant for T and Phi networks under sinusoidal steady state-constant k and m-derived filters-low pass, high pass and band pass filters-effect of cascading multiple sections

Network Functions &Synthesis of Networks
Network Function- Determining network functions, driving point and transfer function, Poles and Zeros, Minimum and Non-minimum phase function, necessary conditions for driving-point function, analysis of time-domain behaviour from pole-zero plots.
Network Synthesis- Positive real functions, Synthesis of LC network- Foster's Reactance Theorem, Separation of Poles and Zeros, Foster's Form-I, Foster's Form-II, Cauer Form. Synthesis of RL, RC series and parallel networks in Foster's Form-I, Foster's Form-II and Cauer Form.

References:

1. Suresh Kumar K.S, *Electric Circuits and Networks*, Pearson,2009.
2. Hayt, William H(Jr), Jack E Kemmerly, Steven M Durbin, *Engineering Circuit Analysis*, McGraw-HillHigherEducation,2020.
3. Franklin Kuo, *Network Analysis and Synthesis*, Wiley, 2006.
4. John D. Ryder, *Network, Lines and Fields*, 2nd Edition, Pearson, 2015

EE3029E OPTIMIZATION TECHNIQUES & ALGORITHMS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total sessions: 39

Course Outcomes:

CO1: Outline an adequate mathematical background on optimization theory
CO2: Analyze the real life problems and formulate them as constrained and unconstrained optimization problems.
CO3: Solve optimization problems using linear optimization techniques
CO4: Solve optimization problems using nonlinear programming (Hessian and gradient) and apply for solving engineering optimization problems

Mathematical Background for optimization

Mathematical background: sequences and subsequences, mapping and functions, continuous functions infimum and supremum of functions minima and maxima of functions, differentiable functions - Vectors and vector spaces - matrices, linear transformation, quadratic forms, definite quadratic forms, gradient and Hessian-Linear equations, solution of a set of linear equations basic solution and degeneracy convex sets and convex cones - convex sets and properties convex hulls, extreme point- Separation and support of convex sets, convex and concave functions, differentiable convex functions

Engineering Optimization problems

Statement of optimization problem- Common Engineering optimization problems - Classification - type and size of the problem.- Minimum cost flow problem - Network path models – Travelling Salesman problem - transportation - assignment problem - allocation problem – Hungarian method - scheduling problem- shortest path problem- Prim's algorithm – Dijkstra's algorithm -

Linear programming

Linear programming: Standard form - Geometry of LP problems-Theorem of LP-Relation to convexity formulation of LP problems - Simplex method and algorithm -Matrix form- two phase method-Duality- dual simplex method-Sensitivity analysis - Artificial variables and complementary solutions

Nonlinear programming

Non-linearity concepts - non-linear programming gradient and Hessian- Unconstrained optimization: First & Second order necessary conditions-Minimization & Maximization-Local& Global convergence-Speed of convergence-Basic descent methods - Gradient methods - Newton Method-Lagrange multiplier method - Kuhn-tucker conditions - Dynamic programming: Multistage decision process- Concept of sub optimization and principle of optimality-Computational procedure- Engineering applications. Optimization programming, tools and Software: MATLAB, FSQP, SOLVER, LINDO etc

References:

1. D. Bertsekas, Nonlinear programming, 2nd Edition, Athena Scientific, 1999, Nashua
2. S.S.Rao, *Engineering Optimization*, 4^{rd} ed., John Wiley & Sons, New Delhi, 2094.
3. R. Fletcher, Practical methods of optimization, 2nd Edition, Wiley, 2000, New York
4. Stephen Boyd & Lieven Vandenberghe, *Convex Optimization,* Cambridge University Press, 2004
5. Shashi Kant Mishra, Bhagwat Ram, *Introduction to Linear Programming with MATLAB*, Chapman & hall (CRC Press), 2017.
6. W.L.Winston, *Operation Research-Applications & Algorithms*, Thomson publications, 2003.
7. K., Deb. *Optimization for engineering design: Algorithms and examples*. Prentice-Hall Of India Pvt. Limited, 2004.

8. Vanderbei, Robert J, *Linear Programming: Foundations and Extensions*, Springer, 2013
9. M. S. Bazaraa, J. J. Jarvis, H. D. Sherali, *Linear Programming & Network Flows*, John Wiley & Sons, 2010.
10. Luenberger, David G, *Linear and Nonlinear Programming*, Springer,2015.

EE3026D ARTIFICIAL NEURAL NETWORKS AND FUZZY LOGIC SYSTEMS

Pre-requisites: Nil

L	T	P	O	C
3	0	0	6	3

Total hours: 39

Artificial Neural Networks

Introduction, Humans and Computers, Organization of the Brain, Biological Neuron, Biological and Artificial Neuron Models, Types of Neuron Activation function, ANN Architectures, learning strategies, supervised, and unsupervised learning, reinforcement learning, Hebb Network, Training Algorithm, Perceptron Model, Training Algorithm, Limitations of the Perceptron Model and Applications, Adaptive Linear Neuron, Training Algorithm, Limitations of the Adaline model, Computer based simulation.

Feed forward and Feedback Neural Networks

Back Propagation Neural Algorithm, Limitations of Back propagation Algorithm, RBF Neural Network – theorem and the separability of patterns, RBF learning strategies, Feedback Neural Networks: Discrete Hopfield Neural Network, Architecture and Algorithm. Unsupervised learning networks: Kohonen Self-organizing Feature Maps, Counter Propagation Networks, Deep Learning Neural Networks: Convolutional Neural Network, Deep Recurrent LSTM model, Applications in Forecasting, Pattern Classification and other Engineering Problems, Computer based simulation.

Fuzzy Logic Systems

Uncertainty and Vagueness, Introduction to Classical sets and relations - Operations and Properties; Type -1 Fuzzy sets and Fuzzy relations, Operations, properties, cardinalities, Composition, Membership Functions, Fuzzification, Membership value assignment, Formulation of fuzzy rule base, Defuzzification to crisp sets, Defuzzification methods, Type – 2 Fuzzy sets, definition, set theoretic and algebraic operations on Type-2 Fuzzy sets, Membership Grades, Cartesian product of Type-2 fuzzy sets, Interval Type – 2 Fuzzy sets, Computer based simulation.

Fuzzy Inference Systems and applications

Fuzzy Inference Systems, Mamdani Fuzzy Models, Takagi - Sugeno Fuzzy Models, Adaptive Neuro-Fuzzy Inference Systems, Fuzzy Logic Control Systems, Fuzzy Cognitive Maps, Dynamics of FCM and application of FCM, Applications of Fuzzy Inference system in function Approximation, Control and Process Monitoring, Fault Diagnosis and other Engineering Applications, Computer based simulation.

References:

1. Simon Haykin, *Neural Networks Comprehensive Foundation*, 2nd ed., Pearson Education, 2005.
2. James A. Freeman, David M. Skapura, *Neural Networks Algorithms, Applications, and Programming Techniques*, Pearson Education India, 1991.
3. S.N.Sivanandam and S.N.Deepa, *Principles of Soft Computing*, Wiley India Pvt Ltd, 3rd edition, 2018.
4. S.Rajasekaran and G.A.Vijayalakshmi Pai, *Neural Networks, Fuzzy Logic and Genetic Algorithm:Synthesis & Applications*, Prentice-Hall of India Pvt. Ltd., 2006
5. Timothy J. Ross, *Fuzzy logic with engineering applications*, McGraw Hill, New York, 2010.
6. Stamatios V Kartalopoulos, *Understanding neural networks and fuzzy logic basic concepts and applications*, Prentice Hall of India (P) Ltd., New Delhi, 2000.
7. Mizutani, E., Jang, J.S.R. and Sun, C.T., *Neuro-fuzzy and soft computing*. First Edition. Pearson Education India. 2015.
8. Goodfellow, I., Bengio, Y. and Courville, A.. *Deep learning*. MIT press. 2016.

EE3031E SPECIAL MACHINES AND LINEAR MACHINES

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Evaluate the performance of a servo motor from machine data and select the right servo motor for a given application.
CO2: Evaluate the performance of stepper motor and associated drive electronics from machine data and select the right stepper motor for a given application.
CO3: Get acquainted with various FHP motors available in the Industry and their application areas.
CO4: Understand the working principle, construction details and classification of linear machines and become familiar with various applications of linear machines at various power levels.

Servo Motors
Servo motors - Types of servomotors: DC servomotor: Basic working principle and its classification, Field controlled and Armature controlled DC servomotor, Application: servo stabilizer and position control system. AC servo motor: construction, operating principle and Application. Symmetrical components applied to two - phase servo motors - equivalent circuit and performance based on symmetrical components - servo motor torque - speed curves.

Stepper Motors
Stepper motors - construction features - method of operation - drive - amplifiers and transistor logic -Drive Circuits - half stepping and the required switching sequence - the reluctance type stepper motor – ratings. Characteristics of Stepper Motor- Stepper motor application.

Special Motors
Reluctance motors - General types of synchronous motors - Reluctance motors - definitions - construction - polyphase and split phase reluctance motors - capacitor type reluctance motors. Hysteresis motors - Construction - polyphase - capacitor type and shaded pole hysteresis motors –Methods of reversing direction of rotation in shaded pole motor. Advantage over reluctance motors, Torque develop and slip
Universal motors – Applications - torque characteristics - essential parts of universal motors - EMF due to main field and cross field - Transformer and rotational emf - circuit model and Phasor Diagram.

Linear Motors
Linear machines - basic difference between LEMS and rotating - machine – classification of LEMS, linear motors and levitation machines - linear induction motors - linear synchronous motors - DC linear motors – linear levitation machines, edge Effect, MMF wave and its velocity, air gap flux density

References:

1. Toro.V.D, *Electric Machines and Power Systems*, Prentice Hall of India, 1985.
2. Veinott, *Fractional Horsepower Electric Motors*, McGraw-Hill, 1948
3. Nasar.S.A,Boldeal, *Linear Motion Electric Machines*, John Wiley,1976
4. V.U.Bakshi, U.A.Bakshi, *Electrical Circuits and Machines*, Technical Publication, Pune, 2008
5. V. V. Athani, *Stepper Motors: Fundamentals Applications and Design*, New Age International 2007.
6. Fitzgerald, Charles Kingsley, Stephen D. Umans, *Electric machinery*, Tata McGraw-Hill 2002.

EE3032E ELECTRIC POWER UTILIZATION

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

CourseOutcomes:

CO1: Analyze the application of electrical energy for traction systems, taking into account economic and technological advancements.
CO2: Evaluate the economic and environmental impact of electric heating systems and make decisions regarding their implementation.
CO3: Design and analysis of illumination levels for lighting systems and gain the knowledge about LED drives and their characteristics.
CO4: Study and analyze the various factors influencing Refrigeration and Air Conditioning systems.
CO5: Acquire basic knowledge about electric vehicles and drives.

Modern Electric Traction and Drives
Electric Traction: Features of an ideal traction system-systems of electric traction-mechanism of train movement-speed-time curve, Traction supply system- transmission and distributing system on AC-DC traction- Modern Electric Traction and drives-system of current collection-traction motors tractive effort and horse power- Speed Control Schemes-Electric braking-challenges in electric traction-technology upgradation in electric traction.

Electric Heating and Analysis
Electric heating: classification- heating element-losses inoven and efficiency- resistance furnace- radiant heating-induction heating- high frequency eddy current Heating-Dielectric heating- arc furnace- heating of buildings- electric ovens, domestic water heaters and other heating appliances and thermostat control circuit. Electric welding Basics-Laser Welding-Types of industrial Loads-Heating and cooling curves of Motor.

Illumination and LED Drives
Illumination: radiant energy-terms and definitions-laws of illumination-luminous efficacy- electrical lamps-design of interior and exterior lighting systems- illumination levels for various purposes- light fittings-LED lighting schemes, Practical LED characteristics, Practical DC and AC drives circuit of LED. Introduction to energy Conservation- Power factor improvement and its necessity.

Refrigeration and Air Conditioning
Refrigeration-Domestic refrigerator and water coolers - Air-Conditioning-Various types of air conditioning system and their applications, smart air conditioning units - Energy Efficient motors: Standard motor efficiency, need for more efficient motors, Motor life cycle, Direct Savings and payback analysis, efficiency evaluation factor.

Electric Vehicle Technology
Electric Vehicle Technology-Requirements-Comparative performance of IC engine and EV- Types of EV and Components-summary of motor selection-energy loss in various drive cycle.

References:

1. JBGupta,*Utilizationofelectricpowerand electrictraction*,SK Katsons, 2013.
2. Wadhwa. C.L., Generation, *Distribution and utilization of electrical energy*, Wiley Eastern Limited,2008.
3. William E.Dewitt, “ *Electric Power and Control*”, Second Edition, Pearson, 2013.
4. J Marcos Alonso, “*LED Lighting and Drivers*” 2019.
5. Steve Winder, “*Power Supplies for LED Driving*, 2nd Edition, Newnes, 2016.
6. Amir Khajepour, Saber Fallah and Avesta Goodarzi, “*Electric and Hybrid Vehicles Technologies, Modeling and Control: A Mechatronic Approach”*, John Wiley & Sons Ltd, 2014.

7. Michael Hilgers and Wilfried Achenbach, "*Electrical Systems and Mechatronics*", 2021.

EE3033E BIOMEDICAL ENGINEERING

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain the fundamental concepts in human physiology and cardiovascular systems.
CO2: Explain the working of various recording instruments for clinical measurements.
CO3: Illustrate the applications of physics and engineering principles in the development of diagnostic instruments.
CO4: Analyse the concepts of imaging and interfacing devices for the development of health care systems.

Biopotentials and Cardiovascular instrumentation
Introduction to electrophysiology – action potential –-electrodes– mono polar and bipolar recording - cardiovascular system – phonocardiography – ECG –Eindhoven‘s law -12 lead system- blood pumps – heart lung machine -– cardiac pace maker –defibrillator

Biomedical Recording instruments and respiratory physiology
Blood pressure measurement –characteristics of blood flow-electromagnetic and ultrasonic blood flow meters-indicator dilution technique – plethysmography. Electroencephalography- Electromyography
Respiratory physiology – measurements in respiratory system –respiratory therapy equipments

Renal physiology and diagnostic instrumentation
Renal physiology – membranes for haemodialysis – haemodialysis machines- lithotripters - Audiometry – Ultrasonics in medicine – Diagnostic ultrasound – Biological Effects of Ultrasound
Physiological effects of electric current – Electric shock hazards

Imaging Systems
Lasers in medicine - X- ray – radio therapy equipment -safety and dosage-medical linear accelerator machine – CT and MRI. Overview of Brain Computer Interface.

References:

1. John G Webster, Medical Instrumentation, Application and Design, 4th Edition, John Wiley &Sons, 2015.
2. Leslie Cromwell, Fred J Weibell, Erich A Pfeiffer, Biomedical instrumentation andMeasurements, 2nd Edition, Pearson Education, 2015.
3. R.S.Khandpur, Handbook of Biomedical instrumentation, 3rd Edition, Tata McGraw-Hill, 2014.
4. John D. Enderle and Joseph D. Bronzino Introduction to Biomedical Engineering, 3rdEdition Elsevier 2012.
5. Joseph D. Bronzino and Donald R. Peterson, The biomedical engineering handbook, 4th Edition,CRC Press Taylor & Francis, 2015
6. Geddes & Baker, Principles of Applied biomedical instrumentation, 3rd Edition, John Wiley & Sons, 2008.

EE3034E ILLUMINATION ENGINEERING

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes

CO1: Understand the need for good illumination and apply the Laws of Illumination for various design.
CO2: Discuss the various electric light sources and their operating characteristics
CO3: Apply the knowledge of the entities in the illumination systems and their units, measurement of illumination, determination of total luminous flux emitted by different shaped sources
CO4: Analysis of various lighting systems, maintenance of lighting system and lighting calculations.
CO5: Design of energy efficient lighting systems

Introduction

State the need for Illumination, Define good Illumination, Radiation - Eye and Vision -The Purkinje effect-performance characteristics of human visual system, External factors of vision-visual acuity, contrast, sensitivity, time luminance, colour, visual perception Laws of Illumination –Candela- Frechner's law - Inverse Square Law - Lambert's Cosine Law of Incidence Photometry and spectrophotometry.

Electric light sources and their operating characteristics

Ratings, operating characteristics of vapor lamps- mercury vapor lamps- sodium vapor lamps. Fluorescent lamps: fundamentals, ratings, cathode types- starters- ballasts- operating characteristics- CFL- Bulb Temperature Vs Light output - Lumen Maintenance Curve. HID lamps, LED lamps-driver circuits

Entities in the illumination systems

Entities in the illumination systems and their units: Illumination, intensity, brightness, solid angle relationships, luminous flux-luminosity- measurement of illumination- Macbeth Illuminometer, Goniophotometer, Integrating sphere, lux meter. Determination of total luminous flux emitted by a plane source, circular disc source, rectangular source, strip source. Photometric experiments

Design of lighting systems

Design of lighting systems- Interior Lighting -Sports Lighting -Road Lighting -Street Lighting-Factory outdoor lighting- Flood lighting -Maintenance of lighting system and Lighting Calculations considering day light. Design of Energy efficient lighting systems. Lighting controllers – dimmers, motion and occupancy sensors, photo sensors and timers.

References:

1. R. H. Simons and A. R. Bean, Routledge;*Lighting Engineering Applied calculations,*1st edition, 2020
2. Partab H, Art and Science of Utilization of Electrical Energy, Dhanpat Rai & Sons, Delhi, 2017.
3. Steffy G, Architectural Lighting Design, 3rd ed., John Wiley & Sons, 2008
4. Boast W.B, Illumination Engineering, McGraw-Hill Book Company, 1953.
5. Cotton H, Principles of Illumination, John Wiley and Sons, 1960.
6. Jack L. Lindsey, Applied Illumination Engineering, PHI,1991

EE3035E LINEAR SYSTEM THEORY

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total sessions: 39

Course Outcomes:

CO1: Develop mathematical models of dynamic systems
CO2: Analyze the system stability by transfer function approach
CO3: Analyze the system response in both time-domain and frequency domain
CO4: Evaluate performance of standard dynamical systems through computer simulations

Concepts of dynamic systems modelling and analysis

Introduction to the concepts of dynamic systems modelling and analysis design and development-Definition of system –System Dynamics--Feedback-Classification of systems- static, dynamic, linear, non-linear, time varying, time invariant, distributed, lumped, continuous time, discrete time, discrete event, systems etc. Modelling of electrical systems- passive networks- dc and ac motors linear models –Concept of transfer function – transfer functions for simple electrical and electromechanical systems. Impulse response and transfer function- convolution –block diagrams and signal flow graphs- Mason’s gain formula.

Modelling of non-electrical systems

Modelling of non-electrical systems- Examples of simple pneumatic, hydraulic and thermal and liquid level systems-control valves - Translational and rotational systems- D’Alembert’s principle-Modelling of electromechanical systems, force-voltage and force-current analogy- Comparison of RLC Circuits and Mass Spring-Damper system-Development of linearised models- Superposition principle-Linearized model for Inverted Pendulum. Introduction to Time delay systems.

Signals and Systems in Frequency Domain

Fourier representation of a periodic signals- Fourier transform and inverse Fourier transform pairs Properties of Fourier transforms. Continuous amplitude and phase spectra - Relation between Laplace transforms and Fourier transforms. Concepts of attenuation, amplification and filtering of signals - Stability of linear systems – open loop and closed loop stability – bounded input bounded output stability -Routh Hurwitz criterion – limitations.

Time domain and Frequency domain analysis of SISO LTI Systems

Time domain and Frequency domain analysis of single input-single output linear time invariant systems Determination of Impulse response-Analysis of response to other standard inputs- step, ramp ,acceleration and sinusoidal inputs- Time domain performance measures for first order and second order systems- underdamped and over-damped systems- Significance of damping factor. Definition of order and type of dynamical systems - steady state and dynamic error - Determination of error constants from transfer functions- Analysis of response of higher order systems- Effect of poles and zeros. Frequency response – Bode plots – performance criteria in frequency domain – band width – cut off frequency – gain margin – phase margin. Computer simulation of systems.

References:

1. David K Cheng, *Analysis of Linear Systems*, Narosa Publishers, 2002.
2. Gene F Franklin, J David Powell and Abbas Emami Naeini, *Feedback Control of Dynamic Systems*, 8h ed., Pearson Education, 2018.
3. M. Gopal, *Control Systems*, 4th ed., Tata McGraw-Hill, 2012.
4. J. J. D’Azzo, C. H. Houpis, S. N. Sheldon, *Linear Control System Analysis & Design with MATLAB*, 6th ed., CRC Press, 2013
5. Burton T.D, *Introduction to Dynamic Systems*, McGraw-Hill, 1994.
6. John Dorsey, *Continuous & Discrete Control Systems*, McGraw-Hill, 2002.
7. Benjamin C Kuo, *Automatic Control Systems, 9th ed*, Oxford University Press, 2014.
8. Norman S Nise, *Control Systems Engineering*, Wiley, 7th Edition, 2014.
9. G. C. Goodwin, S. F. Graebe and M. E. Salgado, *Control System Design*, Prentice Hall India, 2003.

EE3026E DATA STRUCTURES AND ALGORITMS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Acquire basic knowledge of data structures andits various applications in computations

CO2: Acquire basic knowledge of operations like search, insertion, deletion, traversing mechanism etc. on variousdatastructures

CO3: Analyze algorithms and data structures in terms of time and memory complexity of basic operations.

CO4: Solve problems using data structures such as linear lists, stacks, queues, hash tables, binary trees, heaps, tournament trees, binary search trees, and graphs and writing programs for these solutions.

CO5: Solve problems using algorithm design methods such as the greedy method, divide and conquer, dynamic programming, backtracking, and branch and bound and writing programs for these solutions.

Data Structures

Introduction: Simple data structures and applications- Stacks, Queues, Lists, Dictionary- Linked list, Trees, Graphs. Basics of File Structures-Hashing and hash tables. Basic operations like search, insertion, deletion, traversing mechanism etc. on various data structures. Exercises-Data Structures-implementation using pointers-Sets.

Implementation of Data Structures &Algorithm Complexity Types

Implementation of Data Structure using C and Python-Exercises-Trees-Graphs-implementation using arrays and linked list- Binary tree - In-order, pre-order andpost-order traversals-Polishnotations-Expression Tree-Height balance trees-AVL Tree & Red Black Tree- Trees for external search-B Trees.

Basics of Complexity of algorithms: Time and space complexity- Complexity notations- Complexity Analysis-Examples of polynomial complexity-NP and NP Hard Problems.

Design & Analysis of Algorithms

Algorithms-Divide & Conquer-Greedy Methods-Searching Algorithms: Sequential Search — Searching arrays and linked lists. Binary Search — Searching arrays and binary search trees-Sorting Algorithms: n2Sorts — Bubble sort, insertion Sort, selection sort. nlogn sorts — quick sort, heap sort, merge sort. External sort — merge files- Recursion: Recursive algorithms, Analysis of recursive algorithms-Travelling Salesman Problem-Dynamic Programming-Approximation algorithms- Randomized Algorithms-Design for reentrant and thread safe computations.

References:

1. Richard Johnsonbaugh, *Discrete Mathematics*, 5th ed., Pearson Education, 2001.
2. Cormen T.H., Leiserson C.E, Rivest R.L and Stein C, *Introduction to Algorithms*, PrenticeHall India, New Delhi, 2004.
3. Kleinberg John, Eva Tardos, *Algorithm Design*, (Pearson) Dorling Kindersley(India) Pvt Ltd, 2014.
4. Kruse, Robert, C.L. Tondo, Bruce Leung and Shashi Mogalla, *Data Structures and Program Designin C,* Pearson Education, 2007(2013).
5. Mott, Joe L, Abraham Kandel, Theodore P Baker, *Discrete Mathematics for Computer Scientists &Mathematicians*, Prentice Hall India, 2003.
6. Mark Allen Weiss, *Data Structures and Algorithm Analysis in C++*, 3rd ed., Addison Wesley, 2006.
7. Goodrich, Michael T, Roberto Tamassia, *Algorithm Design*, John Wiley & Sons, 2013 reprint.
8. Aho A.V., Hoperoft J.E and Ullman J.D, *Data Structures and Algorithms*, Pearson Education, New Delhi, 1983.
9. Chow, Randy, Theodore Johnson, *Distributed Operating Systems and Algorithm Analysis*, PearsonEducation, 2009.

EE3027E LT AND HT DISTRIBUTION SYSTEMS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes

CO1: Describe and apply general concepts of distribution system, load and energy forecasting.
CO2: Analyze distribution system and carry out network cost modelling.
CO3: Analyze distribution system reliability and assess power quality.
CO4: Describe consumer tariffs, costing and pricing.
CO5: Describe and apply the knowledge of Power capacitors in HT and LT installation.
CO6: Study the aspects of distribution system design and automation.

Distribution System Parameters, Architecture, and Design

Distribution system - General concepts and architectures - Load and energy forecasting - Factors in power system loading - Optimization of distribution system network cost modeling - Economic loading of distribution transformers Consumer services - consumer load control for power shortages - Tariffs-costing, pricing and metering – Overhead and underground lines - Optimum design considerations - Sizing of capacitors – Voltage design calculations

Distribution System Automation and communication

Distribution Automation System: Necessity, System Control Hierarchy - Basic Architecture and implementation Strategies for SCADA and DAC systems - Basic Distribution Management System Functions. Communication Systems for Control and Automation - Wireless and wired Communications - SCADA and DAC communication Protocols, Architectures and user interface

Distribution System Reliability and Power Quality

Electric power quality: Basic definitions – Power quality problems – Voltage variations and quality measures – Harmonics and mitigation
System reliability: Basic definitions and mathematics – Series systems, parallel systems and their combinations – Markov process – Development of state transition models – Interruption indices -

Distribution System Analysis

Load flow analysis of balanced and unbalanced radial distribution system – Load flow analysis of weakly meshed system - Short circuit analysis of balanced and unbalanced radial distribution system - Short circuit analysis of weakly meshed system – Types of faults.

References

1. Turan Gonen, *Electric Power Distribution Engineering*, 3rd edition, CRC Press, 2015
2. Sallam A. A, & Malik O. P, *Electric Distribution Systems*, 2nd edition, Wiley-IEEE Press, 2018
3. B. Das, Power Distribution Automation, IET Power and Energy Series, 2016
4. J. J. Burke, Power Distribution Engineering: Fundamentals and Applications, CRC Press, 1994
5. J. A. Momoh, Electric Power Distribution, Automation, Protection, and Control, CRC Press, 2007
6. T. A Short, Electric Power Distribution Handbook, CRC Press, 2018

EE3038E DIGITAL SYSTEM DESIGN

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze and design a synchronous sequential machine.
CO2: Analyze and design an asynchronous sequential machine
CO3: Apply hardware description language in real life situations.
CO4: Identify the working of various programmable devices and program them for real life examples.

Synchronous Sequential Circuit Design
Basic Synchronous sequential circuit, Moore and Mealy state machines, Analysis of clocked Sequential circuit. Design steps of synchronous sequential circuit, Example problems –sequence detector, parity checker etc. Analysis of sequential circuit implemented with JK and other Flip-flops, Sequential circuit design using JK flip flops and D Flip-flops, State Reduction, State assignment. Algorithmic State Machine charts, Conversion of ASM chart into hardware, clock skew, clock timing constraints.

Asynchronous Sequential Circuit Design
Design procedure for asynchronous sequential circuit, stable and unstable states, Examples, Races, race- free assignment, State reduction for incompletely specified machines, Determination of compatible pairs, state reduction procedure, Circuit hazards, Gate delays, Generation of static hazards in combinational networks, Design of hazard free combinational network, Hazard-free asynchronous circuit design. Dynamic
hazards, Function hazards and Essential Hazards.

System Design using VHDL
Introduction to Verilog, Description of combinational circuits, VHDL model for multiplexers, Signals and Constants, Arrays, VHDL Operators. VHDL for Sequential Logic, Modeling Flip flops, Registers, counters using VHDL, Modeling a Sequential Machine, Digital system testing and Debugging-Fundamentals of digital system testing and debugging - Methods of module debugging and verification -Test bench development

Synchronous design using programmable devices
Programming logic device families – Designing a synchronous sequential circuit using PLA/PAL – Realization of finite state machine using PLD – FPGA – Xilinx FPGA-Xilinx 4000, FPGA design optimization-Area, frequency, power consumption - Improving reliability. Parallel, concurrent and pipelined data processing on FPGA.Designofserial adder with accumulator, Design of binary multiplier, Design of binary divider- Design of simple soft processor.-Practical Aspects: Prototype design of Railway signalling communication and control.

References:

1. Charles H Roth,L Kinney, *Fundamentals of Logic Design*, 7th Edition, Cengage Learning, 2013.
2. Brian Holdsworth, Clive Woods, *Digital Logic Design*, 4th ed., Newness, 2002.
3. Givone Donald, *Digital Principles and Design*, 3rd ed., Tata McGraw Hill, 2017.
4. Nripendra N Biswas, *Logic Design Theory*, Prentice Hall of India, 2001.
5. Parag K.Lala, *Fault Tolerant and Fault Testable Hardware Design*, B S Publications, 2002.
6. Parag K.Lala, *Digital system Design using PLD*, B S Publications, 2003.
7. M.D.Ciletti, Modeling, *Synthesis and Rapid Prototyping with the Verilog HDL*, Prentice Hall, 1999.
8. M.G.Arnold, *Verilog Digital – Computer Design*, Prentice Hall (PTR), 1999.
9. S. Palnitkar, *Verilog HDL – A Guide to Digital Design and Synthesis*, Pearson, 2003.
10. Douglas L. Perry, *VHDL: Programming by Example*, 4th ed, McGraw-Hill, 2002.

EE3039E ADVANCED PROCESSOR ARCHITECTURE AND SYSTEM ORGANISATION

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Demonstrate the working of a modern processor.
CO2: Establish the basic concepts in organization of a modern computer system.
CO3: Develop and test programs for embedded systems using assembly / high-level language.
CO4: Design different sub systems of a computer system, such as ALU, memory, I/O , peripherals etc.

High Performance CISC Architecture
Programmers Architecture of Pentium processor- comparison with Pentium-Pro processor - list of operating modes - Bus Operations – Programming the Pentium processor - Pentium Instruction set (Opcodes)- modes of addressing – Interrupts in Pentium - Brach predication - Paging - floating point unit - Multitasking – Exception handling - internal architecture of Intel Core2 Duo (Simple block diagram only) - important technological features of Ix processors - comparison of Core i3, i5, i7 and i9 processors - Comparison of Intel Skylake, Goldmont and Ice Lake microarchitectures - Vector Processing - Array Processors – Inter-processor Arbitration - Inter-Processor Communication and Synchronization - Cache Coherance - Shared Memory in Multiprocessors.

The ARM Processor
Background of ARM Architecture, Architecture Versions, Processor Naming, Instruction Set Development, Thumb Instruction and Instruction Set Architecture.
ARM Assembly language- Programming using the ARM Instruction Set in Keil Microvision IDE, Data Transfer Instructions, Arithmetic instructions, Branch Instructions, Multiple register instruction - Subroutines - Programming the peripherals of ARM using C and Keil Microvision IDE.

Basic Structure, Instructions and Programming of Computers
Basic Operational Concepts - Bus Structures - Performance – Processor Clock - Basic Performance Equation - Clock Rate - Performance Measurement. Memory Location and Addresses - Memory Operations - Instructions and Instruction Sequencing - Addressing Modes - Basic Input and Output Operations - Stacks and Queues - Additional Instructions - Encoding of Machine Instructions.

Input/Output Organization and Memory System
Accessing I/O Devices, Interrupts – Interrupt Hardware, Direct Memory Access, Buses, Interface Circuits, Standard I/O Interfaces – PCI Bus, SCSI Bus, USB.
Basic Concepts, Semiconductor RAM Memories, Read Only Memories, Speed, Size, and Cost, Cache Memories – Mapping Functions, Replacement Algorithms, Performance Considerations - Introduction to RAID.
Numbers, Arithmetic Operations and Characters, Arithmetic Micro operations, Addition and Subtraction of Signed Numbers, logic micro operations, shift micro operations, Arithmetic logic shift unit.Design of Fast Adders, Multiplication of Positive Numbers, Signed Operand Multiplication, Fast Multiplication, Integer Division. Instruction codes - Computer Registers - Computer instructions – Instruction cycle. Memory
– Reference Instructions - Program control - Micro programmed Control.

References:

1. Barry B. Brey, *The Intel Microprocessors: 8086/8088, 80186/80188, 80286, 80386, 80486, Pentium, Pentium Pro Processor, Pentium II, Pentium III, Pentium 4, and Core2 with 64-bit Extensions : Architecture, Programming, and Interfacing*, Pearson Education India, ISBN:9788131726228.
2. Lyla B Das: *Architecture, Programming and Interfacing of Low-power Processors – ARM7, Cortex-M* ; Cengage publishers, 2017.
3. William Stallings: *Computer Organization & Architecture*, 9th Edition, Pearson, 2015.
4. *Computer Organization* – Carl Hamacher, ZvonksVranesic, SafeaZaky, Vth Edition, McGraw Hill.

5. *Computer Systems Architecture* – M.Moris Mano, IIIrd Edition, Pearson/PHI
6. Lyla B. Das, *The x86 Microprocessors: 8086 to Pentium, Multi cores, Atom and the 8051 Microcontroller*, 2/e, Pearson Education. ISBN-13: 978-9332536821.
7. Andrew N.Sloss, Dominic Symes and Chris Wright " *ARM System Developer"s Guide : Designing and Optimizing System Software*" , First edition, Morgan Kaufmann Publishers, 2004.
8. Intel x86 processors programmer's reference manuals.
9. Intel® 64 and IA-32 Architectures Software Developer's Manual: Vol. 1
10. Structured Computer Organization – Andrew S. Tanenbaum, 4th Edition PHI/Pearson
11. Fundamentals or Computer Organization and Design, - Sivaraama Dandamudi Springer Int. Edition.
12. Computer Architecture a quantitative approach, John L. Hennessy and David A. Patterson, Fourth Edition Elsevier

EE3040E ELECTRIC VEHICLE SYSTEM ENGINEERING

Pre-requisites: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Acquire knowledge about the necessity of electric vehicle and study its building blocks
CO2: Study and understand various power electronics and storage technologies applied to electric drive system
CO3: Understand various possible drive train system for electric vehicle
CO4: Understand communication between major components of electric vehicle
CO5: Model and simulate electric vehicle systems and analyse the performance

Introduction to Electric Vehicles
Introduction to EVs – Architecture of an EV – EV types – Market Survey – Indian Scenario -Configuration of EVs, Performance of EVs – Energy Flow Analysis - Concept of Regenerative Braking Introduction to Traction Batteries - Drive cycle and its importance in system analysis - Component selection for a given drive cycle for a BEV - Single Phase and Three Phase Inverter - VSI and CSI topologies - PWM Techniques- Space Vector PWM- Hysteresis Control - Comparison of PWM techniques.

Vehicle dynamics and Electric drive train
Drive cycles and their impact on the vehicle operation - Vehicle dynamics: Basic Concepts and Terminology - Vehicle dynamics: Longitudinal, Lateral - Electric Drive train Overview - Systems with Linear Motion and Rotating Systems, Types of loads – Four Quadrant Operation - Desired features for an EV motor, intro to various motors available – T-ω characteristics

Energy Storage System
Battery Types and battery pack - Basic battery operation - Battery Chemistry -Li Ion - Electric Vehicle Battery Efficiency and Effects on Performance - Calculation of Electric Vehicle Battery Capacity - Chemical and electrical analysis during charging and discharging – Governing equations and Waveforms, Battery parameters and comparisons, BEV – battery sizing, Modelling of Battery - RC equivalent network Model - Concept of cell balancing - Basic battery management systems - Battery Chargers- Basic requirements for charging systems - Classification of Charging Architectures - Charging Controls - Current Regulations, charging standards and technologies

EV Modelling, Simulation, and communication requirements
Modelling of BEV-Forward looking Model-Driver Perspective, Backward Looking Model-Drive Cycle Perspective - Modelling of Driver - Modelling of Brake Control Unit - Modelling of Vehicle Control Strategy - Modelling of Vehicle Chassis Sizing of Components - Steady State Energy Balance Equation - Powertrain Dimensioning - Peak vs Continuous performance - Type of Drive cycles - Types of Control Strategy - Analysis-Performance - Range - Consumption Prediction - Automotive Sensor and actuators - Communication between major components

References:

1. Goodarzi, Gordon A., Hayes, John G, Electric powertrain: energy systems, power electronics & drives for hybrid, electric & fuel cell vehicles, Wiley 2018
2. Mehradad Eshani, Yimin Gao, Ali Emadi, Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, Fundamentals, Theory and Design, Second Edition, CRC Press, Taylor and Francis Group, 2010.
3. Ned Mohan, Power Electronics Convertor, Applications, and Design, Third Edition, Wiley, 2002.
4. James Larminie John Lowry, Electric Vehicle Technology Explained, Second Edition, Wiley, 2012

EE3041E HEURISTIC METHODS FOR OPTIMIZATION

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1 : Formulate various engineering problems as optimization problems and create objective functions
CO2: Apply genetic algorithms to solve single objective and multi-objective engineering optimization problems
CO3: Apply swarm based optimization algorithms to solve engineering problems
CO4: Apply Tabu search and simulated annealing to solve engineering problems
CO5: Employ software tools for engineering optimization

Introduction to Optimization

Formulation of optimization problems - Engineering optimization problems - modelling, control, scheduling and routing problem, travelling salesman problem, assignment problem - constrained and unconstrained optimization - types of optimization algorithms: single variable optimization, optimal criteria, gradient based methods - Heuristic methods

Evolutionary Algorithms

Genetic algorithm - History of evolutionary algorithms - Advantages of evolutionary computation, Introduction to genetic algorithms, The genetic computation process-natural evolution - parent selection-crossover-mutation-properties - Types of GA - Multi Objective Optimization - Concept of Paretto Solutions - Multi Objective Genetic Algorithms - NSGA 2 - Programming GA using MATLAB

Swarm based optimization

Introduction to Particle Swarm Optimization, background of Particle Swarm Optimization, Discrete PSO, Application to engineering problems – Simulation.
Introduction to Ant colony optimization - behavior of real ants - Ant colony algorithms, Characteristics - distributed computations - positive feedback - use of greedy search and constructive heuristic information - Simulation practices - Other swarm based algorithms.

Simulated Annealing and Tabu Search

Introduction to Simulated Annealing- Algorithm - Applications - Programming Simulated Annealing. Introduction to Tabu Search -Problem formulation - basic Tabu Search Algorithm - Applications - Simulation practice

References:

1. K. Y. Lee, M. A. El-Sharkawi, *Modern Heuristic Optimization Techniques: Theory and Applications to Power Systems*, IEEE Press, 2008.
2. D.E. Goldberg, *Genetic Algorithms in Search Optimization and Machine Learning*, Pearson Education India, 2013
3. Gen, Mitsuo, Runwei Cheng, and Lin Lin. *Network models and optimization: Multiobjective genetic algorithm approach*. Springer Science & Business Media, 2008.
4. M. Clerc, *Particle Swarm Optimization*, ISTE ltd, 2006.
5. K., Deb. *Optimization for engineering design: Algorithms and examples*. Prentice-Hall Of India Pvt. Limited, 2004.
6. K. Deb, *Multi-objective optimisation using evolutionary algorithms: an introduction*. Springer London, 2011.

EE3042E COMPUTER CONTROL OF INDUSTRIAL PROCESSES

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze industrial processes modelled as multivariable systems
CO2: Design multivariable controllers for industrial systems.
CO3: Implement Programmable logic controllers for industrial processes
CO4: Design SCADA and DCS for large-scale systems

Industrial Processes

Introduction to batch process control. Batch distillation column, Batch mixing Tank, Batch reactor. Basic expressions for MIMO systems - Singular value analysis - Process Interaction, Pairing of Input and Outputs, Relative Gain Array (RGA) - Properties and Application of RGA - strategies for reducing control loop interactions, Design of Decoupler.

Control schemes for Industrial Processes

Multi-loop and Multivariable control - Cascade control - Ratio control - feed-forward control - Over-ride - split range and selective control - Introduction to Dynamic Matrix Control - Case Studies: Distillation column, chemical reactor, three element boiler drum, level control, pH control.

Programmable Logic Controllers

Organization of Programmable logic controllers - Hardware details: I/O modules, Power supply, CPU – Standard Programming aspects - Ladder programming - Sequential function charts - Man-machine interface - Case studies.

Control of Large-Scale Systems

Introduction - SCADA Architecture - Different Communication Protocols - Common System Components - Supervision and Control - HMI, RTU and Supervisory Stations – Recent trends in SCADA - Security Issues.
DCS: Introduction to distributed control systems - DCS Architecture - Local Control Unit (LCU) architecture and languages - Process interfacing issues - communication facilities - configuration of DCS, displays, redundancy concept - case studies.

References:

1. D.E. Seborg, T.E. Edgar, D.A. Mellichamp. *Process Dynamics and Control*, Wiley India Pvt. Ltd., Fourth Edition, 2017.
2. Sigurd Skogestad, Ian Postlethwaite, *"Multivariable Feedback Control: Analysis and Design*", John Wiley and Sons, 2005.
3. B.Wayne Bequette, "*Process Control: Modeling, Design, and Simulation*", Prentice Hall of India, 2004.
4. George Stephanopoulos, "*Chemical Process Control – An Introduction to Theory and Practice*", Prentice Hall of India, 2005.
5. F. G. Shinskey, *Process control systems: application, Design and Tuning*, McGraw Hill International Edition, Singapore, 1996.
6. R. C. Dorf and R. H. Bishop, *Modern Control Systems*, Addison Wesley Longman Inc., 2010.
7. Stuart A. Boyer: *SCADA-Supervisory Control and Data Acquisition*, Instrument Society of America Publications, USA, 2016
8. Gordon Clarke, Deon Reynders ,*Practical Modern SCADA Protocols: DNP3*, 60870.5 and Related Systems, Newnes Publications, Oxford, UK, 2004

EE3043E BIO-SIGNAL PROCESSING

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain the principles of acquisition and pre-processing of biosignals
CO2: Describe the principles of electrocardiography and design suitable algorithms for the analysis of ECG signals
CO3: Discuss the principles of electroencephalography and apply methods to extract relevant information from EEG signals.
CO4: Apply the principles of EMG and Evoked Potentials to implement signal processing techniques for the benefit of clinical diagnostics

Introduction to Biomedical Signals and filtering
Introduction to biomedical signals – Action potential generation – Electrocardiogram, Electroencephalogram, Electromyogram, Electroneurogram, Electroretinogram. Basics of bio-signal acquisition – Artefacts and their removal – powerline frequency – baseline wandering – movement artefact – interference from other physiological signals – use of filters – time and frequency domain filtering. Sampling and quantization for biosignals.

ECG Aquisition and Signal Processing
Basic electrocardiography – ECG data acquisition – ECG lead systems – Vectorcardiogram – steps in ECG analysis – ECG parameters and their estimation – QRS detection algorithm -arrhythmia analysis and monitoring - long term ECG recording. ECG data compression techniques – Transformation compression Techniques – other data compression techniques – Prony's method – clinical applications.

EEG Acquisition and Signal Processing
Generation of EEG – 10-20 electrode system system – intracranial electrode system – frequency spectrum of EEG – identification of normal and abnormal brain states from EEG – feature extraction from EEG signals. Linear prediction theory – recursive estimation of AR parameters Spectral error measure – transient detection and elimination (the case of epileptic patients) – review of Wiener Filtering Problem – Principle of adaptive filters – Steepest -Descent Algorithm.

Evoked Potentials and EMG Signal Processing
Introduction to evoked potentials – Auditory and Visual Evoked potentials and their processing.
EMG signal processing – Generation of EMG - Surface and intramuscular EMG – EMG signal decomposition – applications of EMG signal processing – Computer – aided diagnosis.

References:

1. Rangaraj M Rangayyan: *Biomedical Signal Analysis*, John Wiley, 2^{nd} ed, 2015.
2. W. J. Tompkins, *A Biomedical signal processing*, PHI, 2009.
3. D. C. Reddy, *Biomedical signal processing: principle and techniques*, 1st ed., TMH, 2005.
4. L. Sornmo and P Laguna, *Bioelectrical signal processing in cardiac and neurological applications*, Elsevier Academic Press, 2005.
5. R. U. Acharya, J. S. Suri, J. A. E. Spaan, S. M. Krishnan, *Advances in Cardiac Signal Processing*, Springer, 2007
6. J G Proakis& D G Manolakis, *Digital Signal Processing – Principles, Algorithms and Applications*, 4^{th} ed, Pearson 2014.

EE3044E SYSTEM IDENTIFICATION AND PARAMETER ESTIMATION

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply mean squared error-based methods for estimation problems
CO2: Apply maximum likelihood estimation methods for stochastic processes
CO3: Design Kalman Filter for linear and nonlinear estimation problems
CO4: Apply system Identification and estimation for practical problems using software tools

Mean Squared Error (MSE) based Estimation

Formulation of models for linear estimation problems - Statistical framework for parameter estimation - guiding principles behind MSE parameter estimation methods -minimizing prediction errors - linear regression and least squares methods – examples - correlating prediction errors with past data - Instrumental variable method - consistency and identifiability - Recursive methods - Matrix inversion lemma - RLS Algorithm - Weighted RLS - Application in parameter estimation - feature extraction - data analytics - AR and ARMA process modeling and estimation of model parameters - Spectral methods.

Maximum Likelihood estimation (MLE)

Statistical framework for parameter estimation - Stochastic processes – Ergodicity – Stationarity -univariate processes - multivariate processes - Wiener process - Markov process-guiding principles behind MLE parameter estimation methods - maximum likelihood estimation - derivations – examples – simulation - identification of closed loop systems – identification of multivariable systems - examples

State Estimation & Kalman Filter

Derivation of the stochastic estimation problem - Wiener Hopf equation – realizability -examples of realizable filters - stochastic state estimation problem - optimal filtering - derivation of Kalman filter – Simulation - calculation of memory requirements for digital implementation - study of literature in control, guidance and communication on Kalman filter applications - Extended Kalman Filter.

References:

1. J. Schoukens, R. Pintelon and Y. Rolain, *Mastering System Identification in 100 Exercises*, Wiley IEEE Press, 2012.
2. L. Wang and K. C. Tan, *Modern Industrial Automation Software Design*, Wiley-IEEE Press, 2012.
3. R. V. Jategaonkar, *Flight Vehicle System Identification: A Time-Domain Methodology*, 2nd ed., Aerospace Research Central, American Institute of Aeronautics & Astronautics, USA, 2015.
4. Ljung and Lennart, *System Identification: Theory for the user*, Prentice Hall Information Systems Science Series, 1987
5. Sinha, N.K. and Kuszta, B., 1983. *Modeling and identification of dynamic systems* (Vol. 135). New York: Van Nostrand Reinhold Company.
6. Grewal, Mohinder S., and Angus P. Andrews. *Kalman filtering: Theory and Practice with MATLAB*. John Wiley & Sons, 2014
7. Stengel, Robert F. *Optimal control and estimation*. Courier Corporation, 1994.

EE3045E HIGH VOLTAGE ENGINEERING

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course outcomes:

CO1: Apply and analyse various generation and measurement techniques for high voltages and currents.
CO2: Understand the breakdown phenomenon in different insulating mediums.
CO3: Examine the over voltages in power systems and the principles of insulation coordination.
CO4: Design the insulation configuration of high voltage cables.

Generation of High Voltages

Generation of High voltages and currents: AC voltages: cascade transformers-series resonance circuits, Tesla coils. DC voltages: voltage doubler-cascade circuits-electrostatic machines, Impulse voltages: single stage and multistage circuits-wave shaping-tripping and control of impulse generators Generation of switching surge voltage and impulse currents. Simulation of voltage doubler, Cockroft Walton voltage multiplier and Marx impulse voltage generation circuits.

Insulation materials and Breakdown

Introduction to Insulation materials: Classification, insulating materials used in various power equipments. Breakdown in gas and gas mixtures-breakdown in uniform and non uniform fields-Paschen's law, Townsends criterion-streamer mechanism-corona discharge-breakdown in electro negative gases Breakdown in liquid dielectrics-Breakdown in solid dielectrics.

Measurement and Testing

Measurement of high voltages and currents-DC, AC and impulse voltages and currents-DSO-electrostatic and peak voltmeters-sphere gaps-factors affecting measurements-potential dividers (capacitive and resistive)-series impedance ammeters-rogowski coils-hall effect generators. High voltage testing of materials and apparatus-preventive and diagnostic tests-dielectric loss measurements Schering bridge-inductively coupled ratio arm bridge-partial discharge and radio interference measurement, different types of sensors used for PD measurement-testing of circuit breakers and surge diverters.

Over voltages and insulation coordination

Natural causes of over voltages- lightning phenomena - over voltages due to switching surges - system faults and other abnormal conditions for different voltage levels- principles of insulation co-ordination

High voltage cables

Classification of High Voltage Underground cables, insulation materials for cables, general construction of a single core UG cable, 3 core,3 1/2 core and 4 core cables. Essential properties required for insulating material of Underground cables. Methods of laying Underground cables. Faults in Underground cable. Testing of cables

References:

1. Kuffel and Zaengl , High Voltage Engineering Fundamentals, 2nd ed., Newness, 2002
2. M. S. Naidu, V. Kamaraju, High Voltage Engineering, 3rd ed., McGraw-Hill,1995.
3. M. Khalifa, High Voltage Engineering: Theory and Practice, Dekker, 1990.
4. H. M. Ryan, High Voltage Engineering and Testing, IEE 2001.
5. Kuffel and Abdullah.M, High Voltage Engineering, Pergamon press,1978
6. Wadhwa C L, High Voltage Engineering, New Age International, New Delhi,1994
7. Relevant IS standards and IEC standards
8. Electrical Power Generation Transmission and Distribution by S.N.Singh, PHI Publication
9. Standard techniques for high voltage testing, IEEE Publication 1978.

EE3046E EMBEDDED SYSTEMS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Discuss the basics of Embedded Systems.
CO2: Demonstrate the working of a modern processor.
CO3: Develop and test programs for embedded systems using assembly / high-level language.
CO4: Use various peripherals in a digital system to solve engineering problems.
CO5: Design and develop embedded system hardware and software, running over operating systems.

Systems
Application Areas, figures of merit, Categories of embedded systems, Overview of embedded system architecture, desirable features and history. Specialties of embedded systems, recent trends in embedded systems, Architecture of embedded systems, Hardware architecture, Software architecture, Application Software, Communication Software, Embedded System Development Environment and debugging Tools – - IDE, Compilers, Simulators /Emulators
MCU internals - Reset types, Timers, Stacks, Interrupts, DMA, Serial Communication etc. Memory: EPROM, Flash, OTP, SRAM, DRAM, SDRAM etc., Pull up, Pull down and High Z connections , A brief introduction to sensors and actuators and examples of embedded systems

The ARM Processor
Background of ARM Architecture, Architecture Versions, Processor Naming, Instruction Set Development, Thumb-2 and Instruction Set Architecture.
ARM Assembly language- Programming using the ARM Instruction Set in Keil Microvision IDE, Data Transfer Instructions, Arithmetic instructions, Branch Instructions, Multiple register instruction Programming the peripherals of ARM using C and Keil Microvision IDE.
Features of a typical ARM 7 processor –Bus structure Peripherals: GPIO, Timers, Interrupts, Serial Communication New ARM processors –Introduction to the Cortex Series.

Embedded System Design
Embedded System Product Development Life cycle (EDLC), Hardware development cycles- Specifications. Hardware testing methods like Boundary Scan, In Circuit Testing (ICT) etc. Networks for embedded systems - I2C, SPI, AMBA, CAN etc.

Operating Systems
Operating System Fundamentals, Concept of firmware, Operating system basics, General Linux Architecture, Linux Kernel, Linux file systems, Embedded Linux: Booting Process in Linux, boot loaders, U-boot, Kernel Images, Real Time Operating systems, Basics of RTOS: Real-time concepts, Hard Real time and Soft Real-time, Differences between General Purpose OS & RTOS, Basic architecture of an RTOS, Tasks, Processes and Threads, Multiprocessing and Multitasking, Task scheduling, Task communication and synchronisation, Device Drivers.
GNU Tools: gcc, gdb, gprof, Makefiles, Free RTOS/ Chibios-RT

References:

1. Lyla B. Das., *Embedded Systems-an integrated approach*, Pearson Education ,2013
2. Shibu K.V. ,*Introduction to Embedded Systems*, Tata McGraw Hill ,2010.
3. Michael J. Pont ,*Embedded C*, Addison Wesley, 2002.
4. Tim Wilmshurst, *An introduction to the design of small-scale embedded systems*, Palgrave, 2001.
5. Venkateswaran Sreekrishnan, *Essential Linux Device Drivers*, Prentice Hall, 2007.
7. Raj Kamal, *Embedded Systems Architecture Programming and Design*, Tata McGraw Hill, 2001.

8. Jane Liu, *Real-time Systems*, Prentice Hall, 2000
9. Laplante, Phillip, *Real-Time Systems Design and Analysis: An Engineer's Handbook*, 4th ed., IEEE Press, 2012.
10. Simon, David E, *Embedded Software Primer*, Pearson 2012.
11. Lyla B Das: *Architecture, Programming and Interfacing of Low-power Processors – ARM7, Cortex-M* ; Cengage publishers, 2017.
12. J. Cooperstein, *Writing Linux Device Drivers: A Guide with Exercises*, 3rd ed., O'Reilly, 2005.

EE3047E INTRODUCTION TO DATA SCIENCE

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Manipulate and extract information from data
CO2: Construct and apply statistical learning methods for predictive modelling
CO3: Reproduce and present results from data analysis
CO4: Explore techniques for selecting relevant features and engineering new features to improve model performance
CO5: Gain insights into career opportunities and professional development paths in data science.

Introduction to Python for Data Science
Overview of Python's popularity in data science - Setting up Python and data science libraries (e.g., NumPy, Pandas, Matplotlib) - Data Manipulation with Pandas - Introduction to Pandas data structures (Series, DataFrame) - Data cleaning and preprocessing - Data aggregation and transformation

Data Visualization with Matplotlib and Seaborn and Numerical Computing using NumPy
Creating various types of plots - bar charts, line charts, scatter plots, histogram, box plot, pair plot - Customizing plots - Data visualization best practices - NumPy for Numerical Computing: Arrays and vectorized operations - Mathematical functions and operations - Linear algebra with NumPy

Control structure and Statistical Analysis with Python
Control structures- if-else family - for loop - for loop with if break - while loop - Descriptive statistics - Hypothesis testing - Probability distributions - Data Preprocessing - Handling missing data - Feature scaling - Introduction to Data Mining and Clustering: Clustering algorithms (e.g., K-Means, DBSCAN) - Cluster evaluation

Ethical Considerations in Data Science and Project
Data privacy and security - Bias and fairness in machine learning - Introduction to big data tools (e.g., Hadoop, Spark) Working with distributed datasets - Financial and Economic Data Applications
A data science project that integrates the concepts learned throughout the course (Data collection, cleaning, analysis, and visualization, Model building and evaluation)

References:

8. Wes McKinney, *Python for Data Analysis*, O'Reilly
9. Peter Wang and Aron Ahmadia, *Fundamentals of Data Analytics in Python*, Addison Wesley Live Lessons

EE3048E MACHINE LEARNING AND DEEP LEARNING – FUNDAMENTALS AND APPLICATIONS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Learn the practical side of machine learning for applications
CO2: Applying machine learning to solve variety of problems
CO3: Familiarize the fundamentals of deep learning for computer vision and understand how to build neural networks
CO4: Understand major technology trends driving deep learning.
CO5: Get proficient in deep neural networks and its applications

Introduction to Machine Learning
Overview of machine learning - supervised, semi-supervised, unsupervised learning, reinforcement learning
Basics of parameter estimation: maximum likelihood and maximum a posteriori - Bayesian formulation - Classification algorithms - linear and non-linear algorithms - perceptrons -logistic regression, linear discriminant analysis- Quadratic discriminant analysis - naive Bayes, decision trees
Neural networks: concept of perceptron and Artificial neuron, Feed Forward Neural Network, back propagation algorithm, weight

Practical aspects in Machine Learning
Support vector machines and large-margin classifiers - Kernel methods
Regression algorithms - least squares linear regression, gradient descent, closed form, normal equations, regularization techniques (LASSO, RIDGE), polynomial regression, locally weighted regression algorithm
Practical aspects in machine learning: data preprocessing, overfitting, accuracy estimation, parameter and model selection, bias variance tradeoff

Computer Vision and Convolutional Neural Networks
Computer Vision - A historical perspective - Different machine learning tasks - Image Classification - Data-driven Approach, K-nearest neighbour - Linear classification - Loss function, Multiclass SVM, Softmax classifier - Image features optimization, Numeric and Analytic gradients
Convolutional Neural Networks: Back propagation, Gradient-Based Learning - Model of a biological neuron, activation functions - different types, comparison, Convolutional Neural Networks - Convolution / Pooling Layers, spatial arrangement, layer patterns, layer sizing pattern

CNN Architecture
CNN architectures: LeNet, AlexNet, VGG, ResNet, Inception case studies, computational considerations, Recurrent Neural Networks - RNN, Bidirectional RNNs, LSTM, GRU - Applications of RNN: word prediction, Chatbots, Image captioning
Semantic Segmentation, Object Detection: RCNN, Fast RCNN, Faster RCNN, YOLO, Mask RCNN - Understanding and Visualizing Convolutional Neural Networks - Gradient ascent, Deep dream, Texture Synthesis, Neural Style Transfer

References:

1. Ian Goodfellow, Yoshua Bengio, Aaron Courville, Deep Learning, MIT Press, 2016
2. Bishop, C. ,M., Pattern Recognition and Machine Learning, Springer, 2006
3. Michael Nielsen, Neural Networks and Deep Learning

EE3049E INTRODUCTION TO DATA ANALYTICS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand basic statistical techniques and their applications in the context of business and industry problems
CO2: Perform and interpret elementary statistical procedures
CO3: To extract information from data and use it to predict trends and behavior patterns
CO4: Apply data analytics techniques to solve real-world business problems
CO5: Understand how data analysis contributes to decision-making processes

Data Definitions and Analysis Techniques
Elements, Variables, and Data categorization- Need for data, Types of Data, Scale of measurement, Sources of data, Classification and Tabulation of data - Data Visualization - Levels of Measurement, Data management and indexing, Introduction to statistical learning and R-Programming

Descriptive Statistics
Measures of central tendency - Measures of location of dispersions - Practice and analysis with R - Basic analysis techniques - Statistical hypothesis generation and testing - Chi-Square test - Mann-Whitney U-test, Median test, Kruskal-Waliis test - Analysis of variance - Correlation analysis - Karl Pearson’s correlation, Spearman’s rank correlation - Maximum likelihood test - Practice and analysis with R

Data Analysis Techniques
Regression analysis - Simple and Multiple Linear Regression models - Determination of regression coefficients, Coefficient of determination - Significance test of Regression model -Polynomial regression - Classification techniques – Clustering - Association rules analysis - Practice and analysis with R

Multivariable Analysis
Introduction to Multivariate Analysis - Overview of Discriminant Analysis, Factor Analysis, Cluster Analysis, Multidimensional scaling and Conjoint Analysis - Understanding business scenarios - Feature engineering and visualization - Scalable and parallel computing with Hadoop and Map-Reduce - Sensitivity Analysis

References:

1. Probability & Statistics for Engineers & Scientists (9th Edn.), Ronald E. Walpole, Raymond H. Myers, Sharon L. Myers and Keying Ye, Prentice Hall Inc.
2. Advances in Complex Data Modeling and Computational Methods in Statistics, Anna Maria Paganoni and Piercesare Secchi, Springer, 2013
3. The Elements of Statistical Learning, Data Mining, Inference, and Prediction (2nd Edn.), Trevor Hastie Robert Tibshirani Jerome Friedman, Springer, 2014
4. Hadoop: The Definitive Guide (2nd Edn.) by Tom White, O'Reilly, 2014
5. MapReduce Design Patterns: Building Effective Algorithms and Analytics for Hadoop and Other Systems, Donald Miner, Adam Shook, O'Reilly, 2014

EE3050E GRID INTEGRATION OF RENEWABLE ENERGY

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze the concept of distributed generation and technologies
CO2: Investigate the technical challenges of Distributed Generation technologies
CO3: Design the microgrid architectures and its control operation
CO4: Explore smartgrid technologies and infrastructure

Distributed Generation
Modern Power System: Generation - Transmission - Distribution - Loads - Introduction to Distributed Generation (DG) - Technologies of DG - IEEE 1547- Solar photovoltaic generation - wind energy – Wind power plants - Microturbines - Fuel Cell - Storage Systems - batteries, fly-wheels, ultracapacitors – unit sizing of DGs - Case studies

Grid integration issues and challenges
Penetration of DGs Units in Power Systems - Integration of DGs Units in Distribution Network -Modern Power Electronics for DGs Applications – multiple and single input dc-dc converters - ac-dc and dc-ac converters - Technical restrictions - Protection of DGs - Economics of DGs –Pricing and Financing framework for DG units - Optimal placement of DGs - Case studies.

Microgrids
Introduction to Microgrids - AC and DC microgrids - Operational Framework of Microgrids - anti-islanding schemes - Distribution Management System (DMS) - Microgrid System Central Controller (MGCC) – Local Controllers (LC) - Economic, environmental and operational benefits of Microgrids in a distribution network - Demand Response Management in Microgrids - Business Models and Pricing Mechanism in Microgrids - Interconnection of Microgrids

Smart Grids
Introduction to Smart Grids (SG) - Factors affecting the growth of SG - The global reality in the field of smart grids and transition into future grids - Smart Agents - Electronics and communications infrastructure in SG - ICT Technologies - smart meters - metering infrastructures – metering equipment - communication of metering equipment - communication protocols - Metering Data Management Systems (MDMS) - Application of SGs - Interconnections issues between SGs

References:

1. N. Hatziargyriou, *Microgrids: Architectures and Control*, Wiley-IEEE Press, 1st Edition, 2014
2. J. N. Twidell &A. D. Weir, *Renewable Energy Sources*, University press ,Cambridge, 2001
3. James Larminie , Andrew Dicks , *Fuel Cell Systems*, John Weily & Sons Ltd, 2000
4. J. F. Manwell , J. G. McGowan, A. L. Rogers , *Wind Energy Explained*, John Weily & Sons Ltd 2009
5. Loi Lei Lai, Tze Fun Chan, Distributed Generation- Induction and Permanent Magnet Generators, IEEE Press, John Wiley & Sons, Ltd., England. 2007.
6. Amirnaser Yezdani, and Reza Iravani, *Voltage Source Converters in Power Systems Modeling, Control and Applications*, IEEE John Wiley Publications, 2009.

EE3051E INDUSTRIAL AUTOMATION

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Familiar with various automation technologies in manufacturing and process industries.
CO2: Understand various automation tools and methods in manufacturing industry
CO3: Implement various control and automation method in process industries.
CO4: Familiar with various communication technologies in manufacturing and process industries.
CO5: Develop skills in troubleshooting and maintaining automated systems

Introduction to Industrial Automation

Basics of industrial automation - Architecture of Industrial Automation Systems - Measurement Systems Characteristics - Types of sensors - Pressure, Force, Temperature, Torque, and motion sensors- Types of actuators - Signal Conditioning - Data Acquisition Systems- Advanced automation functions, Levels of automations, Automated flow lines and transfer mechanisms, Analysis of transfer lines without storage, Automated flow lines with storage buffers.

Introduction to Automatic Control

PID Control - PID Control Tuning - Feedforward Control Ratio Control - Time Delay Systems and Inverse Response Systems - Special Control Structures - Process Control - Automated Manufacturing Systems-Components, Classification and overview of manufacturing systems, Cellular manufacturing, Flexible manufacturing system (FMS), FMS and its planning and implementation, Automated assembly system – design and types of automated assembly systems, Analysis of multi station and single station assembly machine.

Automation in Process industry

Introduction to computer based industrial automation- Direct Digital Control (DDC), Distributed Control System (DCS) and supervisory control and data acquisition (SCADA) based architectures. SCADA for process industries includes understanding of RTUs, Pumping stations, Evacuation processes, Mass Flow Meters and other flow meters, Leak-flow studies of pipelines, Transport Automation.

Programmable Logic Controller

Programmable Logic Controller (PLC)- Block diagram of PLC, Programming languages of PLC, Basic instruction sets, Design of alarm and interlocks, Networking of PLC, Overview of safety of PLC with case studies. Process Safety Automation: Levels of process safety through use of PLCs, Integrating Process safety PLC and DCS, Application of international standards in process safety control. Distributed Control System- Local Control Unit (LCU) architecture, LCU Process Interfacing Issues, Block diagram and Overview of different LCU security design approaches, Networking of DCS. Introduction to communication protocols- Profibus, Field bus, HART protocols.

References:

1. John W. Webb and Ronald A. Reis, Programmable Logic Controllers: Principles and Applications, 5th Edition, Prentice Hall Inc., New Jersey, 2003.
2. Krishna Kant, Computer - Based Industrial Control, 2nd Edition, Prentice Hall, New Delhi, 2011.
3. M.P.Groover, Automation, Production Systems and Computer Integrated Manufacturing, 5 th Edition, Pearson Education, 2009.

EE3052E FUNDAMENTALS OF ARTIFICIAL INTELLIGENCE

Pre-requisites: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Identify problems where artificial intelligence techniques are applicable
CO2: Apply selected basic AI techniques
CO3: Participate in the design of systems that act intelligently and learn from experience
CO4: Learn how AI can be used to solve complex problems in various domains.
CO5: Explore ethical considerations in AI, including fairness, transparency, and bias mitigation

Introduction to Artificial Intelligence, Problem solving and Search Algorithms
Definition and goals of AI - Historical perspective - AI applications in various domains - Bias and fairness in AI - Ethical AI design and responsible AI usage - AI and society - Problem-solving agents -Uninformed search algorithms - breadth-first search, depth-first search - Informed search algorithms - A, A*, AO* search - Adversarial search - minimax algorithm

Knowledge Representation and Reasoning
Ontologies, foundations of knowledge representation and reasoning, representing and reasoning about objects, relations, events, actions, time, and space; predicate logic, situation calculus, description logics, reasoning with defaults, reasoning about knowledge, sample applications

Planning and Decision making
Planning - planning as search, partial order planning, construction and use of planning graphs - Representing and Reasoning with Uncertain Knowledge - probability, connection to logic, independence, Bayes rule, Bayesian networks, probabilistic inference, sample applications - Decision-Making: basics of utility theory, decision theory, sequential decision problems, elementary game theory, sample applications.

Machine Learning and Knowledge Acquisition
Machine Learning and Knowledge Acquisition - Learning from memorization, examples, explanation, and exploration - Learning nearest neighbour, naive Bayes, and decision tree classifiers, Qlearning for learning action policies, applications - Computer Vision - Image processing fundamentals - Feature extraction - Object detection and image classification - Convolutional Neural Networks (CNNs)

References:

1. George F. Luger, Artificial Intelligence: Structures and Strategies for Complex Problem Solving, 7th ed. Pearson, 2018.
2. Stuart Russell and Peter Norvig, Artificial Intelligence: A Modern Approach, 4th ed. Upper Saddle River, NJ: Pearson, 2020.

EE3055 SOFT COMPUTING

Pre-requisites: Nil

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

Total hours: 39

Soft Computing
Soft Computing: Concept of Computing Systems, Cognition, Brain Computation, Cognitive Learning methods, Adaptation, Adaptation versus Learning, Types of Adaptations, Self-Organizing and Evolution Theory, Hard Computing, Limitations of Hard Computing, Soft Computing versus Hard Computing, Characteristics of Soft Computing, Methods of Soft Computing, Applications of Soft Computing.

Artificial Neural Networks
Artificial Neural Networks: Introduction, Human Brain Structure and its Cognitive Operation, Comparison of Biological and Artificial Neurons, Basic Building Blocks of Artificial Neural Network, Neural Network Architectures, Learning Techniques, Activation Functions, Perceptron Model, Training algorithm, Applications, Back Propagation Neural Network, Training algorithm, Computer Based Simulation.

Fuzzy Logic Systems
Fuzzy Logic Systems: Fuzzy versus Crisp Sets, Crisp sets and Fuzzy Sets – Operations and Properties, Crisp Relations and Fuzzy Relations – Operations and Properties, Composition of Crisp and Fuzzy Relations, Uncertainty and Vagueness, Membership Functions, Fuzzification and its Methods for Membership Value Assignments, Defuzzification and its Methods for Crisp Set Conversion, Definition of Fuzzy Rule Base and their formulation, Computer Based Simulation.

Evolutionary Computing
Evolutionary Computing: Creation of Offsprings and Working Principle, Fitness Function Formulation and Constraints, Single and Multi-objective optimization, Genetic Algorithm – Process flow, Selection Operators, Cross Over Operators, Mutation Operators, Convergence of GA, Particle Swarm Optimization, Concept, PSO Algorithm, Convergence of PSO, Applications to find optimal solutions for engineering problems, Computer Based Simulation.

References:
1. Simon Haykin, *Neural Networks Comprehensive Foundation*, 2nd ed., Pearson Education, 2005.
2. James A. Freeman, David M. Skapura, *Neural Networks Algorithms, Applications, and Programming Techniques*, Pearson Education India, 1991.
4. S.N.Sivanandam and S.N.Deepa, *Principles of Soft Computing*, Wiley India Pvt Ltd, New Delhi, Third Edition, 2018.
5. Timothy J. Ross, *Fuzzy Sets and Fuzzy logic with engineering applications*, Wiley India Pvt Ltd, New Delhi, Fourth Edition, 2022.
6. Stamatios V Kartalopoulos, *Understanding neural networks and fuzzy logic basic concepts and applications*, Prentice Hall of India (P) Ltd., New Delhi, 2000.
7. Mizutani, E., Jang, J.S.R. and Sun, C.T., *Neuro-fuzzy and soft computing*. First Edition. Pearson Education India. 2015.
8. David.E.Goldberg, *Genetic Algorithms in search, optimization and machine learning*, First Edition, Pearson Education India, 2008.

EE4021E ADVANCED DC – AC POWER CONVERSION

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Design proper Modulation Techniques for DC-AC Power Conversion
CO2: Apply the concept of Voltage and current source Inverters.
CO3: Analyze the working of Special type inverters and Soft switching DC-AC inverters
CO4: Evaluate the applications of DC-AC Power Convertors using computer simulation.

Voltage and Current Source Inverter
Voltage source inverters: Analysis and modes of operation of Single-phase half-bridge inverters, Single- phase full-bridge inverters, Three-phase full-bridge VSI. 120 degree and 180 degree operation of three- phase full-bridge inverter. Harmonic analysis. Filter design and simulation practice.
Current source inverters, Three phase full bridge current source inverters, Boost type CSI, Comparison between VSI and CSI, Filter design Applications and simulation practices.

Modulation Techniques for DC-AC Power Conversion
Single-phase and three-phase H-bridge inverter. Various of topologies for DC-AC power conversion- evolution and modes of operation. Purpose of pulse width modulation, Concept of over modulation, Square wave operation of voltage source inverter, Selective harmonic elimination, Sine PWM and filter design. Space vector concept and transformation, Per-phase methods from a space vector perspective, Space vector based modulation, Conventional space vector PWM, identification of sector, dwell time calculation, design of space vector PWM for conventional two level three phase inverter. Simulation practice.

Special type inverters
Impedance source inverters, Quasi-impedance source inverters, Equivalent circuit and operations, Circuit analysis and calculations, Simulation practice, Multilevel DC-AC inverters, Diode-clamped capacitor clamped multilevel inverters, Multilevel inverters using H-Bridges, Generalized multilevel inverters, Mixed level l.,multilevel inverters, Applications and simulation practices.

Soft-switching DC-AC inverters
Notched DC link inverters, Resonant circuits, Design considerations, Resonant pole inverter, Operating, principle, Transformer based resonant DC link inverters, Applications and simulation practices.

References:

1. F. L. Luo and H. Ye, Advanced DC/AC Inverters: Applications in Renewable Energy, CRC Press, 2013.
2. Seguier, Guy, Labrique and Francis, Power Electronic Converters- DC-AC Conversion, Springer, 1993
3. E. dos Santos, E. R. da Silva, Advanced Power Electronics Converters: PWM Converters Processing AC Voltages, Wiley, 2014.
4. A. Yazdani, Voltage–Sourced Converters in Power Systems: Modeling, Control, and Applications, Wiley, 2010
5. D. O. Neacsu, Switching Power Converters: Medium and High Power, CRC Press, 2017.

EE4022E SWITCHED MODE POWER SUPPLIES

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Acquire knowledge about the principles of operation of non-isolated and isolated hard-switched DC-DC converters.

CO2: Acquire knowledge on various loss components in a switched mode converter and choice of switching frequency with a view towards design of such converters.

CO3: Acquire knowledge on magnetics in switched mode converters and design of high frequency inductors with a DC bias and high frequency transformers.

CO4: Introduce voltage mode and current mode control of DC-DC converters and familiarization with various controller ICs available in the market.

CO5: Introduce the student to large-signal modeling and small signal modeling of hard-switched converters, development of transfer functions and design of error amplifiers.

CO6: Introduce the student to transient control in hard-switched converters by use of proper wiring practices, judicious component selection and various snubbers.

Non-Isolated DC to DC Converters

Linear Regulation versus Switched Mode Regulation, Basic DC-DC Converter Structures and Two Basic Principles for steady-state analysis of DC-DC Converters.

Buck, Boost, Buck-Boost SMPS Topologies - Basic Operation - Waveforms - Modes of operation CCM, DCM and BCM – Ideal Waveforms and relations in all three modes – Effect of switch resistance, diode cut-in voltage, diode resistance, series resistance of inductor, ESR of capacitor etc. on input-output relation of these converters.

Voltage Mode Control Principles.

Analysis of Switching in a Buck Converter (use MOSFET as the switching device for this topic) - switching stresses - Reverse recovery of diodes - Switch-ON time and Switch-OFF time-switching and conduction losses.

Switch-OFF Snubber and Switch-ON Snubber for MOSFET/IGBT based SMPS Units – Selection of Snubber component size and impact of parasitic inductances on snubber component values - choice of switching frequency in a given converter design problem.

Gating Circuits for MOSFETs and IGBTs – Requirement for Level Shifting and/or Isolation – Pulse Transformer Isolated Gate Driver Circuits – Opto-Isolated Gate Drivers – Level Shifting Gate Drivers

Isolated DC to DC Converter Topologies

Need for & advantages of employing a high frequency isolation transformer in SMPS designs – Single-ended *Forward Converter* – need for tertiary winding – effect of leakage inductance on input-output relation of Forward Converter – Double-ended Forward Converter

Push-Pull DC-DC Converter – Flux Walking Problem and Solution – Effect of leakage inductance on input-output relation

Half-Bridge DC-DC Converter – Waveforms, Relations, Component Stresses in CCM mode – Selection of Voltage Splitting Capacitors – Flux Walking problem and solution.

Full-Bridge DC-DC Converter

Flyback Converter in DCM and CCM – Waveforms and Design Relations for DCM and CCM Designs – Effect of Leakage inductance - Passive Voltage Clamp Design –

Design of Magnetics

Ferrite material and its magnetic properties – Ferrite Cores – A_c , A_w , A_L and area product of ferrite cores of various shapes – *Design of Inductors with DC Current Bias using air-gapped Ferrite Cores – Output equation of various isolated converters – Design of high-frequency transformers using Ferrite cores* – core selection – winding

calculations – winding layout – use of litz wire and foil windings - estimation of core loss in Inductor and Transformer designs – Copper loss in Inductors and transformers – Skin effect and Proximity effect – Use of Dowell's curves for copper loss estimation.
Current Transformers for sensing switched currents and their design using Toroidal ferrite cores.

Modeling & Control of SMPS Units
Small-signal Modeling of Converters for Control Design -The switching function – Switched model of a DC-DC Converter – Local Average of variables in a fixed-frequency Switched Mode Converter- The duty-ratio function versus duty-ratio – Local Average Model for a Switched Mode Converter – State Space Average Model (which is an approximate version of local average model) – Solving for steady-state behavior from SSA Model – Linearised SSA Model and Small Signal Transfer Functions for Buck & Boost Converters – Effect of operating point and ESR of Capacitor on small signal transfer functions, the RHP zero in Boost Converter model
Design of Type-I, Type-2 and Type-3 Compensators for Voltage Mode Control of SMPS based on small-signal transfer functions – Realization of these compensators using Opamps and Transconductance Amplifiers – Study of SG3525 VMC PWM Control IC
Current Mode Control – Advantages – Subharmonic Instability – Slope Compensation – Ideal Slope for Slope Compensation – Design of Outer Voltage Control Loop in Current Mode Controlled Converter – Study of UC3842 CMC PWM Control IC
Principles of One Cycle Control as applied to DC-DC Converters
EMI Generation and Filtering in SMPS - Conducted and Radiated Emission Mechanisms in SMPS. Techniques to reduce emissions, Shielding and Grounding- Power Circuit Layout considerations for reducing EMI.EMI Filtering at Input and Output- Effect of Input side EMI Filter on SMPS Control Dynamics.

References:

1. Abraham I Pressman - *Switching power supply design* – 2nd edition 1998 Mc-Graw hill Publishing Company.
2. Keith H Billings -*Switch mode power supply handbook* – 1st edition 1989 Mc-Graw hill Publishing Company.
3. Sanjaya Maniktala - *Switching power supplies A to Z.* – 1st edition 2006, Elsevier Inc.
4. Daniel M Mitchell : *DC-DC Switching Regulator Analysis*. McGraw Hill Publishing Company
5. Ned Mohan et.al : *Power Electronics*. John Wiley and Sons.
6. Otmar Kilgenstein : *Switched Mode Power Supplies in Practice*. John Wiley and Sons.
7. Mark J Nave : *Power Line Filter Design for Switched-Mode Power Supplies*. Van Nostrand Reinhold, New York.

EE4023E POWER SEMICONDUCTOR DEVICES

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Select most suited semiconductor devices for an application circuit.
CO2: Analyse and design protection circuits for semiconductor devices
CO3: Design gating circuits for semiconductor devices
CO4: Become familiar with wide band gap devices and design driver circuits for them.

Power diode, Thyristor, DIAC, TRIAC and GTO

Power Diode: Basic Structure and I-V Characteristics. Breakdown Voltages and Control. On State Losses. Switching Characteristics. Turn on Transients. Turn off Transients. Reverse Recovery Transient. Schottky Diodes. Snubber Requirements for Diodes and Design of Diode Snubbers.

Thyristor: Basic Structure and V-I Characteristics. Operation of thyristor – explain turn on process, turn off process, switching and conduction. Turn-on Transients and di/dt limitations. Turn off Transient. Turn off time and reapplied dv/dt limitations. Ratings of Thyristors. Snubber Requirements and Snubber Design.

DIAC: Basic Structure and operation. V-1 Characteristics. Ratings

TRIAC: Basic Structure and operation. V-1 Characteristics. Ratings. Snubber Requirements. Gate Turnoff Thyristor (GTO): Basic Structure and Operation.

GTO Switching Characteristics. GTO Turn on Transient. GTO Turn off Transient. Minimum ON and OFF State times. Maximum Controllable Anode Current. Overcurrent protection of GTOs.

Power BJT and Power MOSFET, IGBT

Power BJT: Basic Structure and 1-V Characteristics. Breakdown Voltages and Control. Second Breakdown and its Control- FBSOA and RBSOA Curves - On State Losses. Switching Characteristics. Resistive Switching Specifications. Clamped Inductive Switching Specifications. Turn on Transient. Turn off Transient. Storage Time. Base Drive Requirements. Switching Losses. Device Protection- Snubber Requirements for BJTs and Snubber Design - Switching Aids.

Power MOSFET: Basic Structure. V-1 Characteristics. Turn on Process. On State operation. Turn off process. Switching Characteristics. Resistive Switching Specifications. Clamped Inductive Switching Specifications - Turn on Transient and di/dtlimitations. Turn off Transient. Turn off time.Switching Losses. Effect of Reverse Recovery Transients on Switching Stresses and Losses - dv/dtlimitations. Gating Requirements. Gate Charge -Ratings of MOSFETs. FBSOA and RBSOA Curves. Device Protection -Snubber Requirements

Basic Structure and Operation. Latch up IGBT Switching Characteristics. Resistive Switching Specifications. Clamped Inductive Switching Specifications - IGBT Turn on Transient. IGBT Turn off Transient- Current Tailing - Ratings of MOSFETs. FBSOA and RBSOA Curves. Switching Losses - Minimum ON and OFF State times - Switching Frequency Capability – Overcurrent protection of IGBTs. Short Circuit Protection. Snubber Requirements and Snubber Design. New power semiconductor devices.

Wide Bandgap Semiconductors and Opto-electric Devices

Wide band gap semiconductors: Types of Wide Band Gap Semiconductors and its properties: GaAs, SiC, GaN etc. Comparison of electric Breakdown field and resistance of wide band gap devices. Conduction loss, switching loss calculation of SiC and GaN devices. Reverse recovery process and comparison. Driver circuit requirement of SiC and GaN devices. Separate control of turn-on and turn off time.

Opto-electric Devices: Types of opto-electic devices: Photodiodes (PDs), Light-Emitting Diodes (LEDs), Laser Diodes (LDs), PV cell etc. I-V Characteristics of PDs, LEDs, LDs and PV cells, Equivalent circuit model of PDs, LEDs and PV cell, the characteristic equation of PV Cell and LEDs. Thermal management of LEDs. Driver Design for LED string.

References:

1. Ned Mohan et.al ,*PowerElectronics*,John Wiley and Sons,2006.
2. G. Massobrio, P. Antognet, *Semiconductor Device Modeling with Spice*, McGraw-Hill, Inc.,1988.
3. B. J. Baliga, *Power Semiconductor Devices*,Thomson, 2004.
4. V. Benda, J. Gowar, D. A. Grant, *Power Semiconductor Devices. Theory and Applications*, John Wiley & Sons 1999.
5. Kiyoshi Takahashi, Akihiko Yoshikawa ,Adarsh Sandhu, *Wide Bandgap Semiconductors- Fundamental Properties and Modern Photonic and Electronic Devices*, Springer 2007.

EE4024E POWER ELECTRONIC DRIVES

Pre-requisites: NIL

L	T	P	O	C
3	1	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Select a dc drive for a particular application based on power rating.
CO2: Select a dc drive based on mechanical characteristics for a particular drive application.
CO3: Operate and maintain solid state drives for speed control of DC machines.
CO4: Model and analyze Induction Motor
CO5: Select a suitable rotating Induction machine for an electrical drive.
CO6: Select a suitable power electronic converter for an IM drive.

Introduction to Drives:
Characteristic matching of the load and the motor - Criteria for selection of subsystems of the Drive -Thermal consideration – considerations in the match between the Power Electronics converter and the motor - Characteristics of mechanical systems - stability criteria.

Modelling of DC Machine:
Theory of operation – Induced EMF – Equivalent circuit and electromagnetic torque – Elecrtomechanical modeling – state space modeling – Block diagram.

Phase controlled DC motor Drives:
Field Control – Armature Control – Four quadrant operation – Single phase controlled convertors – Three phase controlled convertors – half controlled convertor – Converters with freewheeling – Converter configuration for a four quadrant DC motor drive – Steady state analysis of Three phase converter controlledDC motor drive – Two quadrant, Three phase converter controlled DC motor drive. Two quadrant DC motordrive with field weakening- Harmonics and Associated problems – Effect of field weakening.

Chopper Controlled DC motor Drive:
Principle of operation of chopper – Four quadrant chopper circuit and its operation in all quadrants - Modelof chopper – Steady state analysis of chopper controlled DC motor drive- Torque pulsations.
Modelling of Induction Machine:
Principle of operation, Equivalent circuit, Modeling and characteristics.

Speed control of Induction Motors:
Stator voltage control – Stator Frequency control – Pole changing method - Rotor resistance control – Slip power recovery method.
Frequency Controlled Induction Motor Drives:
Voltage Source Inverter (VSI) – VSI fed Induction motor - constant V/F control – Constant Flux control – Constant Slip-speed control – Torque pulsation – Effect of harmonics and its control - PWM control – Flux weakening operation.

References:
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1. N. Mohan, *Power Electronics*, Wiley, 2011.
2. G. K. Dubey, *Fundamentals of Electrical Drives*, 2nd ed., Narosa, 2001.
3. R. Krishnan, *Electric Motor Drives, Modeling, Analysis, and Control*, Pearson Education, 2001.
4. G.K.Dubey and C. R. Kasaravada, *Power Electronics & Drives*, Tata McGraw-Hill, 1993.
5. W. Shepherd, L. N. Hulley, *Power Electronics & Control of Motor*, Cambridge University Press, 2005.
6. Dubey, *Power Electronics Drives*, Wiley Eastern, 1993.

7. M. Chilikin, *Electric Drives*, 2nd ed., Mir publications, 1976.
8. V. Subrahmanyam, *Electric Drives Concepts and applications*, 1st ed., Tata McGraw-Hill, 1994.

EE4025E OPTIMAL AND ADAPTIVE CONTROL

L	T	P	O	C
3	0	0	6	3

Total Sessions: 39

Course Outcomes:

CO1: Analyse optimization of functionals with and without constraints
CO2: Formulate performance index and solve optimal control problems.
CO3: Apply dynamic programming to solve optimal control problems.
CO4: Design direct and indirect adaptive control schemes for dynamical systems

Calculus of variations approach for Minimization of functionals
[Revise the state space analysis and design techniques of linear systems-No class time allotted]
Basic mathematical concepts - Calculus of variations approach- Maximization of functionals of a single and several independent functions - Euler-Lagrange Equation - Constrained extremals - extremal of functionals with dependent functions - differential equation constraints – isoperimetric constraints.

Variational Approach to Optimal Control
Optimal control problem –performance measure - Optimal control problem formulation - Open loop and closed loop form of optimal control - the variational approach to solving optimal control problems - necessary conditions and boundary conditions for optimal control using Hamiltonian – closed loop control for linear regulator problem - linear tracking problem – Pontryagin’s minimum principle - state inequality constraints - minimum time problems - minimum control effort problems.

Dynamic programming
Dynamic programming - principle of optimality - application to multi stage decision making – application to optimal control problem recurrence relation of dynamic programming - discrete linear regulator problem - Hamilton-Jacobi-Bellman equation - continuous linear regulator problem.

Model reference adaptive control
Introduction to Direct and In Direct Adaptive control, Model reference adaptive control - Design method based on the use of Lyapunov function – design of gain scheduled controllers.

References:

1. E. Kirk, *Optimal Control Theory: An Introduction*, 10th ed, Prentice-Hall, 2007.
2. B. D. O. Anderson and J. B. Moore, *Optimal Control: Linear Quadratic Methods*, Prentice-Hall, 2007.
3. M. Krstic, P. V. Kokotovic and I. Kanellakopoulos, *Nonlinear and Adaptive Control Design*, John Wiley and Sons, 1995.
4. K. J. Astrom and B. Wittenmark, *Adaptive Control*, 2nd ed., Courier Corporation, 2013.
5. G. Feng and R. Lozano, *Adaptive Control Systems*, Oxford University Press, 1999.
6. Naidu DesineniSubbaram,*Optimal Control Systems*, CRC Press, Boca Raton London New York Washington, D.C, 2002
7. Liberzon, Daniel. *Calculus of variations and optimal control theory: a concise introduction*. Princeton university press, 2011.

EE4026E POWER SYSTEM STABILITY AND CONTROL

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Model and analyze of power system components - generators, transmission lines, excitation and prime mover controllers and interpret power system stability problems.
CO2: Analyze stability of single machine and multi-machine systems using digital simulation and small-signal analysis techniques.
CO3: Analyze Sub Synchronous Resonance and Counter measures.
CO4: Assess Voltage Stability using PV Curves.

Automatic Generation Control
Generation Control Loops, AVR Loop, Performance and Response, Automatic Generation Control of Single Area and Multi Area Systems, ALFC loop-tie line bias control, Static and Dynamic Response of AGC Loops, Economic Dispatch and AGC.

Transient Stability Analysis
Transient Stability Problem, Modeling of Synchronous Machine, Loads, Network, Excitation and Systems, Turbine and Governing Systems, Trapezoidal rule of Numerical Integration Technique for Transient Stability Analysis, Data for Transient Stability Studies, Transient Stability Enhancement Methods, Equal area criterion to asses stability of a SMIB system, limitations of classical model of synchronous machines.

Low frequency Oscillation and Countermeasures
Low Frequency Oscillations, Power System Model for Low Frequency Oscillation Studies, Improvement of System Damping with Supplementary Excitation Control, Introduction to Sub Synchronous Resonance, and Counter measures, power system stabilizers.

Voltage Stability Analysis
Voltage Stability Problem, Real and Reactive Power Flow in Long Transmission Lines, Effect of ULTC and Load Characteristics on Voltage Stability, Voltage Stability Limit, Voltage Stability Assessment Using PV Curves QV curve – PQ curve – analysis with static loads – loadability limit, Voltage Collapse Proximity Indices, Voltage Stability Improvement Methods.

References:

1. O. I. Elgerd, *Electric Energy System Theory: An Introduction*, 2nd ed., McGraw Hill Education; 2nd edition, 1983.
2. J. Wood and B. F. Wollenberg, *Power Generation, Operation And Control*, 3rd ed., John Wiley And Sons, New York, 2013.
3. J. Arrillaga, C. P. Arnold and B. J. Harker, *Computer Modeling Of Electrical Power Systems*, 2nd ed. Wiley, New York, 2001.
4. P. M. Andersson and A. A. Fouad, *Power System Control and Stability*, 2nd Edition, Wiley Interscience 2003.
5. J. Nagrath and D. P. Kothari, *Power System Engineering*, McGraw Hill Education (India) Private Limited, Uttar Pradesh, 2019.
6. Yao-Nan Yu, Electric *Power System Dynamics*, Academic Press, 1983.
7. P. Kundur, *Power System Stability and Control*, McGraw Hill, New York, 1994.
8. Van Cutsem, T. Vournas, *Voltage Stability of Electric Power Systems*, Springer US, 2007.
9. T. J. E. Miller, *Reactive Power Control in Electric Power Systems*, John Wiley and Sons, New York, 1982.

10. Peter W., Saucer, Pai M.A., “Power System Dynamics and Stability, Pearson Education (Singapore), 9th Edition, 2007.

EE4027E FLEXIBLE AC TRANSMISSION

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Discuss the power flow control in AC systems and FACTS Devices.

CO2: Analyze static series compensation, static shunt compensation and different types of compensators in each category.

CO3: Analyze the operation and control of Unified Power Flow Controller and Demonstrate through simulation.

CO4: Analyze and Demonstrate Special purpose FACTS controllers and custom power devices through simulation.

FACTS and Power Flow Control

FACTS concepts and general system considerations: Power flow in AC systems - Real and Reactive Power flow control Definition of FACTS - Power flow control -Constraints of maximum transmission line loading - Benefits of FACTS Transmission line compensation- Uncompensated line -shunt compensation - Series compensation -Phase angle control.

Static Compensators

Static shunt compensators: SVC and STATCOM - Operation and control of TSC, TCR and STATCOM - characteristics and control, Compensator control - Comparison between SVC and STATCOM. Static series compensation: GCSC, TSSC, SSSC -Static voltage and phase angle regulators - TCVR and TCPAR Operation and Control –Applications- Modeling and Simulation.

Unified and Interline Power Flow Controllers

Unified Power Flow Controller: Circuit Arrangement, Operation and control of UPFC- Basic Principle of P and Q control- independent real and reactive power flow control- Applications - Introduction to interline power flow controller- comparison with other FACTS devices -Applications-Modeling and Simulation.

Special Purpose FACTS Controllers

Special purpose FACTS controllers - Thyristor controlled voltage limiter - Thyristor controlled voltage regulator - Thyristor controlled braking resistor - Thyristor controlled current limiter Custom Power - Compensation Devices - STS - SSC - SVR -Backup energy supply devices, DVR, D-STATCOM and UPQC.

References:

1. N. G. Hingorani and L. Gyugyi, *Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems*, IEEE Press, 2000.
2. T.J.E Miller, *Reactive Power Control in Electric Systems*, John Wiley & Sons, 2010.
3. N. Mohan et.al., *Power Electronics*, 3rd ed., John Wiley and Sons, 2002.
4. K. R. Padiyar, *FACTS controllers in power transmission and distribution*, New Age International (P) Ltd, 2008.
5. X.P.Zhang, C.Rehtanz, B.Pal*Flexible AC Transmission System Modelling and Control*, Springer,2006

EE4028E SWITCHGEAR AND PROTECTION

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Identify causes of overvoltages and faults in power systems.
CO2: Analyse various relaying strategies and standards used.
CO3: Determine relays settings for various scenarios.
CO4: Interpret protection schemes for various power system elements.
CO5: Recognize the advantages of digital relays over conventional relay.
CO6: Apply the suitable signal processing techniques for protection.

Over voltages and Causes of Fault
Overvoltages – Surges and travelling waves – Wave propagation on transmission lines - reflection and attenuation- Lightning strokes- protection against lightning - earth wires- lightning diverters – surge absorbers - arcing ground - neutral earthing - basic concepts of insulation levels and their selection - BIL – Co-ordination of insulation-Simulation of overvoltages using EMTP software.

Art of relaying
Protective Relaying - Qualities of relaying - Definitions - Codes- Standards; Characteristic Functions; Classification – analog - digital- numerical; schemes and design-factors affecting performance –zones and degree of protection; faults-types and evaluation; Instrument transformers for protection.

Digital Relaying
Basic elements of digital protection –signal conditioning- conversion subsystems- relay units-sequence networks-fault sensing data processing units- FFT and Wavelet based algorithms: least square and differential equation based algorithms-travelling wave protection schemes; Relay Schematics and Analysis Over Current Relay-Instantaneous/Inverse Time –IDMT Characteristics; Directional Relays; Differential Relays- Restraining Characteristics; Distance Relays: Types Characteristics. Relay coordination- Relay setting calculations. Primary and backup protection, application and philosophy with applied relay engineering examples

Apparatus and System protection
Digital Protection of power system apparatus – protection of generators – Transformer protection – magnetizing inrush current – Application and connection of transformer differential relays – transformer over current protection. Bus bar protection - line protection - distance protection–long EHV line protection -Power line carrier protection - Protection of Motors, reactors, boosters and capacitors in an interconnected power system; Pilot wire and Carrier Current Schemes. System grounding –ground faults and protection; Load shedding and frequency relaying; Out of step relaying; Re-closing and synchronizing.

References:

1. A.G.Phadke, James S.Thorp, *'Computer Relaying for Power Systems'*, 2ndEJohn-Wiley and sons, 2009.
2. Waldemar Rebizant , Janusz Szafran, and Andrzej Wiszniewski. "*Digital Signal Processing in Power System Protection and Control"*, Springer Publication, 2011.
3. A.T.Johns and S.K.Salman*,'Digital Protection for Power Systems"* , IEEE Power Series, 1997
4. Stanley H. Horowitz, Arun G. Phadke, and Charles F. Henville. *'Power System Relaying'*, 5th Edition, John Wiley & Sons 2022
5. D N Vishwakarma, Badri Ram, and Soumya R Mohanty. '*Power System Protection and Switchgear'*, 3rd Edition. McGraw Hill, 2022

EE4029E ELECTRICITY MARKETS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand the principle and working of electricity markets.
CO2: Illustrate how electricity is priced in deregulated power markets.
CO3: Explain the working of various electricity markets around the world.
CO4: Study the effect of deregulation on transmission and distribution systems.

Power market fundamentals

Why deregulate? What to deregulate? Pricing power, energy, and capacity, Power supply and demand, Market structure and architecture: Spot market – Day ahead market – Real time market – Reserve market – Ancillary services.

Electricity pricing

Concept of marginal cost, Market equilibrium, Market clearing price, Congestion pricing fundamentals, Locational marginal pricing, Operating reserve pricing, Value-of-lost-load pricing, Pricing losses on lines, Pricing losses at nodes, Derivative markets: Hedging risk - Contract for difference – Forwards – Futures - Options – Swaps.

Markets around the world

US and European market evolution, Reforms in Indian power sector, Power Exchanges, Power purchase agreements, Current trends and future scope of electricity markets.

Local energy markets

Virtual power plant and microgrids, Microgrid prosumer consortium, Role of DSO, Business models, Revenue generation from Roof-top solar PV, Net and Gross Feed-in-Tariff.

References:

1. Daniel S. Kirschen, Goran Strbac, ‘Fundamentals of Power System Economics’, Wiley, 2018.
2. Steven Stoft, *‘Power System Economics: Designing Markets for Electricity’*, Wiley-IEEE Press, 2002.
3. Anna Creti, Fulvio Fontini, *‘Economics of Electricity’*, Cambridge University Press, May 2019.
4. Loi Lei Lai, *‘Power System Restructuring and Deregulation’*, Wiley, 2001.
5. Jin Zhong, *‘Power System Economic and Market Operations’*, CRC Press, 2018.
6. Kankar Bhattacharya, Math H. J. Bollen, Jaap E. Daalder, *‘Operation of Restructured Power System’*, Springer, 2001.
7. Mohammad Shahidehpour, Muwaffaq Alomoush, *‘Restructured Electrical Power Systems: Operation: Trading, and Volatility’*, Marcel Dekker Inc., 2001.
8. Mohammad Shahidehpour, Hatim Yamin, Zuyi Li, ‘*Market Operations in Electric Power Systems: Forecasting, Scheduling, and Risk Management*’, IEEE Press, 2002.
9. Indian Energy Exchange: http://www.iexindia.com/
10. Power Exchange India Limited: http://www.powerexindia.com/
11. Indian Electricity Regulations: http://www.cercind.gov.in/

EE4030E POWER SYSTEM OPERATION AND CONTROL

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Formulate and implement control objectives and operational constraint for optimal power flow.
CO2: Analyze and solve economic dispatch of thermal units, unit commitment.
CO3: Discuss automatic generation control and voltage regulation during normal operation of power system augmented with FACTS devices.
CO4: Analyze economic interchange of power and energy between interconnected utilities.

Economic Dispatch and Optimal Power Flow Problem
Economic dispatch of thermal units and methods of solution- Optimal power flow solution- Transmission losses- B matrix loss formula- Take-or-pay fuel supply contract- Composite generation production cost function solution by gradient search techniques, Dynamic programming methods.

Unit Commitment
Unit commitment - Solution methods-Hydrothermal coordination - Scheduling problems - Short term hydrothermal scheduling problem – Pumped storage hydro plants - Hydro scheduling using linear programming - Short term hydro scheduling.

Automatic Generation Control
AGC - Single and multi area system - Speed governing – Generation allocation. AGC with optimal dispatch - TG response - ALFC loop - tie line bias control – AVR: Exciter types - Modeling - AVR loop. Methods of system voltage control - Tap changing transformer-Shunt and series compensation - Synchronous condensers - Static VAR Systems - FACTS controllers - simulation exercise.

Energy Economy and Contingency Analysis
Interchange of power and energy- Economy interchange between interconnected utilities- inter - utility economy energy evaluation- capacity interchange - diversity interchange - energy banking- emergency power interchange – Inadvertent power Exchange- power pools-Transmission Effects and issues- Power system security - Contingency Analysis Using Network Sensitivity Method And AC Power Flow Method - security constrained optimal power flow - state estimation – case study on standard test system.

References:

1. J. Wood and B. F. Wollenberg, *Power Generation, Operation And Control*, 3rd ed., John Wiley And Sons, New York, 2013.
2. A. Gomez-Exposito, A.J. Conejo and C. Canizares, *Electric Energy systems analysis and operation*, CRP press, 2009.
3. P. Kundur, *Power System Stability and Control*, McGraw Hill, New York, 1994.
4. A. K. Mahalanabis, *Computer Aided Power system analysis and control*, Tata McGraw-Hill, 1991.
5. O. I. Elgerd, *Electric Energy System Theory: An Introduction*, 2nd ed., McGraw Hill Education; 2nd edition, 1983.
6. A. Chakrabarti, D. P. Kothari, A. K. Mukhopadhyay, Abhinandanan De, “*Introduction to Reactive Power Control and Voltage Stability in Power Transmission Systems*”, Prentice Hall India Pvt., Limited, New Delhi, 2010
7. J.J. Grainger and W.D. Stevenson Jr, “*Power System Analysis*”, McGraw-Hill Inc., New York, 1994.
8. Antonio J. Conejo, Luis Baringo, “*Power System Operations*”, Springer International Publishing, New York, 2017

EE4031E NONLINEAR SYSTEM ANALYSIS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total hours: 39

Course Outcomes:

CO1: Analyse the characteristics of nonlinear systems.
CO2: Assess the stability of dynamical systems.
CO2: Evaluate the nonlinear systems using frequency domain methods.
CO3: Analyse stability of nonlinear systems
CO4: Design of controllers for nonlinear systems using feedback

Introduction to nonlinear systems
Nonlinear phenomena - different types of nonlinearities and their occurrence – Equilibrium points - Linearization - classification of equilibrium points - stability of equilibrium points - Phase plane analysis - limit cycles in phase plane - existence of limit cycle – Poincare Bendixon theorems – Poincare Index - stability of limit cycles- analysis of systems with piecewise constant inputs using phase plane analysis.

Stability Analysis of Nonlinear Systems
Notions of stability - Lyapunov stability - local stability - local linearization and stability in the small- Direct method of Lyapunov - generation of Lyapunov function for linear and nonlinear systems – variable gradient method - region of attraction - Invariance theorems - Centre manifold theorem - Input output stability - L stability - L stability of state models - L2 stability.

Analysis of Nonlinear feedback systems
Harmonic Linearisation and Describing Function Method-Harmonic linearization - filter hypothesis – Sinusoidal Input describing function (SIDF) of standard nonlinearities- study of limit cycles (amplitude and frequency) using SIDF- Dual Input Describing function – Passivity – Loop transformation - Circle criterion **–** Popov criterion.

Nonlinear Control Techniques
Feedback Control and Feedback Stabilisation- Analysis of feedback systems- Concepts of Inverse control - Design via linearization- stabilization - regulation via integral control - gain scheduling -Feedback linearization - Input state linearization - input output linearization - state feedback control - stabilization - tracking - integral backstepping control.

References:

1. Hassan K Khalil, *Nonlinear Systems*, 3rd edition, Prentice Hall International (UK), 2002.
2. J. J. E. Slotine and W. Li, *Applied Nonlinear Control*, Prentice Hall, New Jersey, 1991
3. S. Strogatz, *Nonlinear Dynamics and Chaos*, 2nd Edition, CRC Press, 2018
4. S. Wiggins, *Introduction to Applied Nonlinear Dynamical Systems and Chaos*, 2nd ed, Springer Verlag, 2003.
5. M. Gopal, *Digital Control and State Variable Methods*, 4th edition, Tata McGraw Hill, 2017.
6. K P Mohandas, *Modern Control Engineering*, Revised Edition, Sanguine Pearson, 2010.

EE4032E ANALOG MOS CIRCUITS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Select the optimum model for MOS transistors, resistors and capacitors for Spice Simulation of a proposed Analog MOS System design.
CO2: Acquire knowledge on basic analog MOS application structures in order to use them as building blocks in designing analog MOS subsystems.
CO3: Employ CMOS Opamps to design common signal processing subsystems.
CO4: Apply mixed-signal CMOS building blocks designing analog MOS subsystems.

Basic MOS Device:
Analog MOS models – Device construction, Principle of operation, static characteristics, Body effect on static characteristics and DC biasing, VVR explanation and use, channel length modulation – Early Voltage, low frequency model – MOS in saturation –high frequency model – MOS resistors and resistor circuits

Single-Stage Amplifiers
Single-Stage Amplifiers-– common source –common gate – common drain amplifiers, cascode and folded cascode structures
Current sources and sinks – regulated cascode current source/sink, Wilder current source
Passive and Active current mirrors – Basic Current mirrors-cascode current mirror – Wilson current mirror – Active Current mirror

Differential amplifiers
Differential amplifiers – Basic differential pair, common mode response.
Frequency response of amplifiers- General considerations of Miller effect, common source, common gate, common drain amplifiers, cascade and differential pair.
CMOS Operational amplifiers – Basic one and two stage CMOS OAs, folded cascade type.

Mixed signal circuits
Mixed signal circuits – CMOS comparator design – analog multiplier – dynamic analog circuits – charge injection and capacitive feed through in
Introduction to switched capacitor circuits- MOSFET as switch – sample and hold circuits– switched capacitor filters
Ring Oscillator, LC oscillator, VCO - PLL, Charge pump PLL, delay locked loops and applications.

References:

1. Adel S. Sedra and K. C. Smith, ‘*Microelectronic circuits*’ 4th edition, Oxford University Press, 2003
2. Jacob Baker R., Li H.W.& Boyce D.E., `*CMOS - Circuit Design, Layout & Simulation*’, PHI,2005.
3. Behzad Razavi, ‘*Design of Analog CMOS Integrated Circuit*’ Tata-Mc GrawHill, 2002.
4. Roubik Gregorian & Gabor C Temes, ‘*Analog MOS Integrated Circuits for Signal Processing*’, John Wiley, 1986.

EE4033E POWER QUALITY

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Understand the causes for various Power Quality issues and their impact on operation and life of various electrical equipment in a power system.

CO2: Perform impedance scan analysis and identify harmonic resonance conditions with the help of suitable software.

CO3: Understand the operation of various Active Power Factor Correction Schemes.

CO4: Develop understanding on the role of SVCs and STATCOMs in improving Power Quality

Overview of Power Quality

Power Quality –overview of power quality phenomena -Basic terminologies –Power Quality Issues – Causes for reduction in Power Quality –– Power Quality Standards and indices.

Voltage Sag and Harmonics

Voltage sags-Causes of voltage sags – magnitude & duration of voltage sags – effect on drives and peripherals– monitoring & mitigation of voltage sags. Interruptions -Origin of Long & Short interruptions – influence on various equipment – monitoring & mitigation of interruptions. Harmonics-important harmonic introducing devices-SMPS-Three phase power converters-arcing devices saturable devices-harmonic distortion of fluorescent lamps-effect of power system harmonics on power system equipment and loads.

Power Factor Improvement

Power factor improvement- Passive Compensation- Passive Filtering- Harmonic Resonance - Impedance Scan Analysis- Active Power Factor Corrected Single Phase Front End-Control Methods for Single Phase APFC Three Phase APFC and Control Techniques- PFC Based on Bilateral Single Phase and Three Phase Converter static var compensators-SVC and STATCOM.

Power Quality Enhancement Techniques

Active Harmonic Filtering-Shunt Injection Filter for single phase, three-phase three-wire and three-phase four wire systems-d-q domain control of three phase shunt active filters -UPS-constant voltage transformers- series active power filtering techniques for harmonic cancellation and isolation. Dynamic Voltage Restorers for sag, swell and flicker problems. Grounding and wiring-introduction-NEC grounding requirements-reasons for grounding-typical grounding and wiring problems-solutions to grounding and wiring problems.

References:

1. G. T. Heydt, *Electric Power Quality*, Stars in a Circle Publications, 1991.
2. M. H. Bollen, *Understanding Power Quality Problems*, 1st ed., IEEE Press, 2001.
3. J. Arrillaga, *Power System Quality Assessment*, John Wiley, 2000.
4. J. Arrillaga, B. C. Smith, N. R. Watson & A. R. Wood, *Power system Harmonic Analysis*, Wiley, 1997.
5. W. E. Kazibwe, M. H. Sendaula, *Electric Power quality control techniques*, Van Nostrand Reinhold, New York, 1993.
6. J. Schlabbach, D. Blume and T. Stephanblome ,*Voltage quality in Electrical Power Systems*, No. 36. IET, 2001.
7. R. C. Dugan, M. F. McGranaghan, S. Santoso and H. W. Beaty, *Electrical power systems quality*, 3rd ed., Tata McGraw-Hill, 2012.
8. G. J. Walkilesh, *Power Systems Harmonics*, Springer, 2007.
9. R. S. Vedam and M. S. Sarma, *Power Quality VAR Compensation in Power Systems*, CRC press, 2009.

10. Bhim Singh, Ambrish Chandra and Kamal Al-Haddad, "*Power Quality: Problems and Mitigation Techniques*", Wiley 2015.

EE4034E STATIC VAR COMPENSATION AND HARMONIC FILTERING

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain the fundamental principles of Passive and Active Reactive Power Compensation Schemes at Transmission and Distribution level in Power Systems.
CO2: Illustrate various single-phase and three-phase Static VAr Compensation Schemes and their controls.
CO3: Develop analytical modeling skills needed for modeling and analysis of such Static VAr systems with a view towards Control Design
CO4: Demonstrate the fundamental principles of Passive and Active Harmonic Filtering in Power Systems.
CO5: Analyze various single-phase and three-phase active harmonic filtering systems employing Current - regulated PWM VSI and their control.
CO6: Analyze and Model Active Harmonic Filtering systems with a vision towards Controller Design

Fundamentals of Load & System Compensation

Fundamentals of Load Compensation – Unbalance and Asymmetry in Linear and Non-linear loads- Symmetrical Components – Instantaneous and Average Power in Symmetrical Components and harmonics – Negative Sequence Current Compensation in Three-Wire Systems by Passive Reactance – Negative Sequence and Zero-Sequence Current Compensators using Passive Reactance – Steinmetz Compensator - Power Quality Issues . Sags, Swells, Unbalance, Flicker, Distortion, Current Harmonics - Sources of Harmonics in Distribution Systems and Ill Effects - Steady-State Reactive Power Control in Electric Transmission Systems- Shunt Reactive Compensation Systems – SVG, SVC and STATCOM – Reactive Power Compensation for Voltage Support – Mid-point Reactive Power Compensation for improved stability margin.

Shunt and Series Reactive Compensation

Static Reactive Power Compensators and their control. Shunt Compensators, SVCs of Thyristor Switched and Thyristor Controlled types and their control, STATCOMs and their control, Series Compensators of Thyristor Switched and Controlled Type and their Control, SSSC and its Control, Sub-Synchronous Resonance and damping, Use of STATCOMs and SSSCs for Transient and Dynamic Stability Improvement in Power Systems.

Converters for Static Compensators

Converters for Static Compensation - Single Phase and Three Phase Converters and Standard Modulation Strategies (Programmed Harmonic Elimination and SPWM) - GTO Inverters - Multi-Pulse Converters and Interface Magnetics - Multi-Level Inverters of Diode Clamped Type and Flying Capacitor Type and suitable modulation strategies (includes SVM) - Multi-level inverters of Cascade Type and their modulation - Current Control of Inverters.

Active Harmonic Filtering

Passive Harmonic Filtering - Single Phase Shunt Current Injection Type Filter and its Control - Three Phase Three-wire Shunt Active Filtering and their control using d-q modeling - Three-phase four-wire shunt active filters - Hybrid Filtering using Shunt Active Filters - Series Active Filtering in Harmonic Cancellation Mode- Series Active Filtering in Harmonic Isolation Mode - Dynamic Voltage Restorer and its control – Unified Power Quality Conditioner.

References:

1. T.J.E Miller, ‘ *Reactive Power Control in Electric Systems’*, John Wiley & Sons,1982.
2. N.G. Hingorani & L. Gyugyi, ‘*Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems*’, IEEE Press, 2000.
3. Ned Mohan et.al, ‘*Power Electronics*’, John Wiley and Sons 2006

4. R. Sastry Vedam &Mulukutla S. Sarma, '*Power quality VAR compensation in power systems*', CRC press, 2009.
5. K.R. Padiyar, "*FACTS controllers in power transmission and distribution*', New age international publications, 2008.

EE4035E SMART GRID ENGINEERING

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Determine conceptual ideas of Smart Grid with a thorough understanding of various communication technologies and power management issues with smart grid.
CO2: Analyze issues related with integration of various distributed energy sources to smart grid.
CO3: Analyze the operation and importance of demand side management, power market scenarios in deregulated scenarios.
CO4: Elaborate the various infrastructure and technologies for substation and feeder automation
CO5: Select various infrastructure and technologies for consumer domain of smart grid

Overview of Smart grid
Introduction to Smart Grids – Today's Grid versus the Smart Grid - Key functions of smart grid - Opportunities & Barriers of Smart Grid - Smart grid elements and control layers - Policies and infrastructures - Concept of Resilient & Self-Healing Grid - Demand Side Management (DSM) and transactive energy models - Present development & International policies on Smart Grid. Case study of Smart Grid

Smart Metering and Demand-Side Integration
Evolution of Electricity Metering - Smart Meters - SmartAppliances, Smart Sensors, Home & Building Automation -Advanced Metering Infrastructure (AMI) - AMI Protocols – Standards and Initiatives - Demand Side Management and Demand Response Programs – Pricing models - Demand Pricing and Time of Use - Real Time Pricing - Peak Time Pricing

Communications in Smart Grid
Communication aspects - Elements of communication and networking - architectures, standards and adaptation of power line communication (PLCC) - Communication models- Home area networks (HAN) and neighborhood area networks (NAN) - IP Protocols - Big data analytics and CLOUD computing - Security for Smart Grid - Wide area Monitoring Systems (WAMS) - PMU and PDCs - Special relaying schemes for Smart Grid

Operations on Smart Grid
The economics of supply and demand in energy markets - Energy market deregulation. Technology Drivers, Smart energy resources- Plug-in hybrid vehicles, Smart substations, Substation and Feeder Automation, Transmission systems: EMS, FACTS and HVDC, Protection and control, Distribution systems: DMS, Volt/VAr control, Fault Detection, Isolation and service restoration, Outage management. Grid Data Management. – Applications of smart grid to power systems - Case studies and test beds for the smart grid

References:

1. James Momoh, Smart Grid: Fundamentals of Design and Analysis, Wiley-IEEE Press, 2012.
2. Lars T. Berger and Krzysztof Iniewski, Smart Grid Applications, Communications, And Security, Wiley, New Delhi, Aug 2015.
3. Takuro Sato, Daniel M. Kammen,Bin Duan, Martin Macuha, Zhenyu Zhou, and Jun Wu, Smart Grid Standards: Specifications, Requirements, and Technologies, Wiley-Blackwell, Apr 2015
4. Janaka Ekanayake, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, and Nick Jenkins, Smart Grid: Technology And Applications, Wiley, New Delhi, Aug 2015.

EE4036E ADVANCED DIGITAL SIGNAL PROCESSING

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total sessions: 39

Course outcomes

CO1: Design Optimum IIR and FIR filters
CO2: Analyse speech signals using frequency domain methods.
CO3: Analyse and process 2D images
CO4: Apply wavelets for signal processing.

Optimisation Methods for IIR and FIR filter Design
Deczky's method for IIR filter design in the frequency domain, Pade approximation method, Least- squares design method in time domain; Frequency sampling method for FIR filters, Parks and McClellan Algorithm for design, Remez exchange algorithm for implementation.

Speech signal processing
Digital models for speech signal, Mechanism of speech production, Acoustic theory, Lossless tube models, Formulation of LPC equation, Solution of LPC equation, Levinson Durbin algorithm, Schur algorithm, Spectral analysis of speech, Short time Fourier analysis, Speech coding, sub-band coding, Transform coding, Channel vocoder, Formant vocoder, Cepstral vocoder, Vector quantisation coder.

Two-dimensional signal processing (Image Processing)
Digital image representation; 2-D DFT. properties; DCT; Image enhancement, Spatial and frequency domain filtering methods; colour image processing; Image restoration- Degradation model, Inverse filtering; Fundamentals of image compression.

Wavelet Theory and applications
Introduction Stationary and non-stationary signals, Signal representation using basis and frames, Time-frequency analysis, Classes of wavelets.
Continuous Wavelet Transform (CWT), Construction of continuous wavelets - Inverse continuous wavelet transform, Redundancy of CWT, Zoom property, Filtering.
Discrete Wavelet Transform (DWT), Non-linear approximation in the Wavelet domain, Construction and Computation of the DWT, Parameterization of discrete wavelets, Bi-orthogonal wavelet bases. **Applications**: Detection of signal changes and denoising, analysis and classification of audio signals using CWT.

References:

1. Alan V Oppenheim, Ronald W. Schafer, *Discrete-Time Signal Processing*, 3rd ed., Pearson Education India Pvt. Ltd., 2021.
2. John G. Proakis, and Dimitris G. Manolakis, *Digital Signal Processing*, 5th ed., Pearson Education India Pvt. Ltd., 2021.
3. L.R. Rabiner and R.W Schafer, *Digital processing of speech signals*, 1st ed., Pearson Education India Pvt. Ltd., 2003.
4. R. C. Gonzalez and R.E. Woods, *Digital Image processing*, 4th ed., Pearson Education India Pvt. Ltd., 2017.
5. Jae S. Lim, *Two-Dimensional signal and image processing*, 1st ed., Prentice Hall Inc., Englewood Cliffs, New Jersey, 1989.
6. Raghuveer Rao and Ajit S. Bopardikar, *Wavelet transforms: Introduction, Theory and applications*, Pearson Education Asia, 2012.

7. J.C. Goswami and A.K. Chan, *Fundamentals of Wavelets: Theory, Algorithms, and Applications*, 2nd ed., Wiley, 2011.
8. Michel Misiti, Yves Misiti, Georges Oppenheim and Jean Michel Poggi, *Wavelets and their Applications*, 1st ed., John Wiley & Sons, 2010.

EE4037E CONTROL AND GUIDANCE ENGINEERING

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total sessions: 39

Course outcomes:

CO 1: Identify the features of navigation systems.
CO 2: Design guidance systems from various components
CO 3: Develop dynamic models of space vehicles and implement control strategies.
CO 4: Design guidance schemes for control of space vehicles and missiles

Introduction to Navigation systems
Fundamentals of Navigation - geometric concepts of navigation - reference frames- Euler angles-direction cosine matrix- quaternion representation- coordinate transformations- comparison of transformation methods. Inertial navigation- inertial platforms- stabilized platforms – gimballed and strapdown INS – IMU Navigation equations- Schuler principle and mechanization- Basics of satellite based navigation systems- Global Positioning Systems (GPS) and Global Navigation of Satellite Systems (GNSS).

Guidance Systems
Guidance information requirements-Energy Conservation Methods-TimeConservation Methods-Collision Warning and Avoidance-Rendezvous - Satellite Orbit maintenance-Inertial navigation-block diagram representation of essential components-Inertial sensors, Gyros: Principle of operation-TDF and SDF- gyro precession-Nutation-gimbal - lock-gimbal flip-gyro transfer function- rate gyro-integrating gyroConstructional details and operation of floated rate integrating gyro-Dynamically tuned gyro-Ring laser gyro-Fiber optic gyro -gyro performance parameters- Accelerometers-transfer function-Pendulous gyro integrating accelerometer Vibrating String accelerometer- Accelerometer performance parameters.

Space vehicle dynamics and control
Powered flight-unpowered flight-Orbital mechanics- Orbital parameters- circular, elliptical, parabolic, hyperbolic and rectilinear orbits- energy of the orbit- orbital transfer and rendezvous- LEO, SSPO,GSO,GTO orbits- impulse transfer between circular orbits- Hoffmann transfer- other co-planar and non-coplanar transfers- N-body problem- two-body problem- Re-entry of space vehicle- re-entry dynamics- ballistic re-entry- skip re-entry- double-dip re-entry- aerobraking- lifting body re-entry- entry corridor- equilibrium glide- thermal and structural constraints- commanded drag guidance. Simulation of space vehicle dynamics.

Missile guidance and Control
Taxonomy of Guidance Laws - Command and Homing Guidance - Classical Guidance Laws : Pursuit, LOS, CLOS, BR, Proportional Navigation and Its Variants such as PPN, BPN, APN, TPN, GPN and IPN.
Modern guidance Laws - PPN with Non-Manoeuvring and Manoeuvring Targets – Qualitative analysis

References:

1. Kaplan, Marshall H. *Modern spacecraft dynamics and control*. Courier Dover Publications, 2020..
2. H. Schaub and J. L. Junkins, *Analytical Mechanics of Space Systems*, AIAA, USA, 2003.
3. E. V. B. Stearns, *Navigation and Guidance in Space*, Prentice Hall, 1983.
4. Lawrence, Anthony. *Modern inertial technology: navigation, guidance, and control*. Springer Science & Business Media, 2nd Ed., 2001.
5. P. Zarchan, *Tactical and Strategic Missile Guidance*, AIAA, 2007.
6. Ching-Fang Lin, *Modern Navigation, Guidance and Control Processing*, Prentice-Hall Inc., Engle Wood Cliffs, New Jersey, 1991

7. George M. Siouris, *Missile Guidance and Control System*, Springer Verlag , New York Inc., 2004.
8. Kabamba, P.T. and Girard, A.R., *Fundamentals of Aerospace navigation and guidance*. Cambridge University Press, 2014
9. R. Yanushevsky, *Modern Missile Guidance*, CRC Press, 2008.
10. N.A.Shneydor: *Missile guidance and pursuit: Kinematics, Dynamics and Control,* Harwood Publishing, 1998.

EE4038E ECONOMIC EVALUATION OF POWER PROJECTS

Pre-requisite: nil

L	T	P	O	C
3	0	0	6	3

Total lecture sessions: 39

Course Outcomes

CO1: Conduct a basic cost-benefit analysis of power projects
CO2: Differentiate the different aspects of power system expansion planning
CO3: Distinguish the different metering techniques for distributed generation
CO4: Analyze and evaluate the economics of power projects through case studies

Considerations in Project Evaluation

Fundamentals of Generation, Transmission and Distribution - Value of Electricity – Integrated Resource Planning – Environmental Concerns and Efficiency – Energy Return on Energy Invested – Capacity Factor – Rehabilitating, Retrofitting and Repowering of Existing Power Facilities - Global Electrical Power Scene - Project Selection and Evaluation – Project Development – Pre-investment stage – Investment Stage – Operational Stage – Post Operational Phase

Evaluation of Power Generation Projects

Cost of Power Generation – Levelized Cost of Energy – Generation Planning – Investment Analysis– Time Value of Money – Net Present Value – Benefit/cost Ratio – Payback Period - Profit/investment Ratio – Business Economic Feasibility Study – Power Purchase Agreements – Case studies on development and evaluation of renewable and non-renewable energy projects

Investing in Transmission

The Nature of the Transmission Business – Barriers to transmission development – Macrogrid proposals - Cost-Based Transmission Expansion – Value-Based Transmission Expansion – TSO economics – Interregional coordination – Cost-Benefit Analysis

Distribution System Finance

Tariff and Energy Bills – Financing Distributed Generation Projects – Net Metering – Net Feed-in - Rooftop Solar PV Business models – Grid-Connected and Stand-alone PV systems - Customer Savings Analysis – Grid Parity – Utility and DSO economics

References:

1. *Hisham Khatib, 'Economic Evaluation of Projects in the Electricity Supply Industry', 3rd edition, IET, 2014.*
2. *Marcelino Madrigal and Steven Stoft, 'Transmission Expansion for Renewable Energy Scale-Up', 2012, Washington DC, World Bank.*
3. *Santosh Raikar, Seabron Adamson, 'Renewable Energy Finance: Theory and Practice', Elsevier, 2019.*
4. *Daniel S. Kirschen, Goran Strbac, 'Fundamentals of Power System Economics, Wiley, 2018.*
5. *Steven Stoft, 'Power System Economics: Designing Markets for Electricity', Wiley-IEEE Press, 2002.*