Item No. - 124
AC- 23/7/2020

UNIVERSITY OF MUMBAI

Bachelor of Engineering

in

Electrical Engineering

Second Year with Effect from AY 2020-21

Third Year with Effect from AY 2021-22

Final Year with Effect from AY 2022-23

(REV- 2019 'C' Scheme) from Academic Year 2019 – 20

Under

FACULTY OF SCIENCE & TECHNOLOGY

(As per AICTE guidelines with effect from the academic year 2019–2020)

Item No. - 124
AC- 23/7/2020

UNIVERSITY OF MUMBAI

Syllabus for Approval

Sr. No.	Heading	Particulars
1	Title of the Course	**Second Year B.E. Electrical Engineering**
2	Eligibility for Admission	**After Passing First Year Engineering as per the Ordinance 0.6242**
3	Passing Marks	**40%**
4	Ordinances / Regulations (if any)	**Ordinance 0.6242**
5	No. of Years / Semesters	**8 semesters**
6	Level	~~P.G.~~ / **U.G.**/ ~~Diploma / Certificate~~ (Strike out which is not applicable)
7	Pattern	~~Yearly~~ / **Semester** (Strike out which is not applicable)
8	Status	**New** / ~~Revised~~ (Strike out which is not applicable)
9	To be implemented from Academic Year	**With effect from Academic Year: 2020-2021**

Date

Dr. S. K. Ukarande
Associate Dean, Faculty of Science and Technology
University of Mumbai

Dr Anuradha Muzumdar
Dean, Faculty of Science and Technology
University of Mumbai

Preamble

To meet the challenge of ensuring excellence in engineering education, the issue of quality needs to be addressed, debated and taken forward in a systematic manner. Accreditation is the principal means of quality assurance in higher education. The major emphasis of accreditation process is to measure the outcomes of the program that is being accredited. In line with this Faculty of Science and Technology (in particular Engineering) of University of Mumbai has taken a lead in incorporating philosophy of outcome based education in the process of curriculum development.

Faculty resolved that course objectives and course outcomes are to be clearly defined for each course, so that all faculty members in affiliated institutes understand the depth and approach of course to be taught, which will enhance learner's learning process. Choice based Credit and grading system enables a much-required shift in focus from teacher-centric to learner-centric education since the workload estimated is based on the investment of time in learning and not in teaching. It also focuses on continuous evaluation which will enhance the quality of education. Credit assignment for courses is based on 15 weeks teaching learning process, however content of courses is to be taught in 13 weeks and remaining 2 weeks to be utilized for revision, guest lectures, coverage of content beyond syllabus etc.

There was a concern that the earlier revised curriculum more focused on providing information and knowledge across various domains of the said program, which led to heavily loading of students in terms of direct contact hours. In this regard, faculty of science and technology resolved that to minimize the burden of contact hours, total credits of entire program will be of 170, wherein focus is not only on providing knowledge but also on building skills, attitude and self learning. Therefore in the present curriculum skill based laboratories and mini projects are made mandatory across all disciplines of engineering in second and third year of programs, which will definitely facilitate self learning of students. The overall credits and approach of curriculum proposed in the present revision is in line with AICTE model curriculum.

The present curriculum will be implemented for Second Year of Engineering from the academic year 2020-21. Subsequently this will be carried forward for Third Year and Final Year Engineering in the academic years 2021-22, 2022-23, respectively.

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Incorporation and Implementation of Online Contents from NPTEL/ Swayam Platform

The curriculum revision is mainly focused on knowledge component, skill based activities and project based activities. Self learning opportunities are provided to learners. In the revision process this time in particular Revised syllabus of 'C ' scheme wherever possible additional resource links of platforms such as NPTEL, Swayam are appropriately provided. In an earlier revision of curriculum in the year 2012 and 2016 in Revised scheme 'A' and 'B' respectively, efforts were made to use online contents more appropriately as additional learning materials to enhance learning of students.

In the current revision based on the recommendation of AICTE model curriculum overall credits are reduced to 171, to provide opportunity of self learning to learner. Learners are now getting sufficient time for self learning either through online courses or additional projects for enhancing their knowledge and skill sets.

The Principals/ HoD's/ Faculties of all the institute are required to motivate and encourage learners to use additional online resources available on platforms such as NPTEL/ Swayam. Learners can be advised to take up online courses, on successful completion they are required to submit certification for the same. This will definitely help learners to facilitate their enhanced learning based on their interest.

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Preface By BoS

The outcome based course curriculum for the undergraduate degree in Electrical Engineering in Rev.2019 'C' scheme has been chalked out through the thoughtful discussions and deliberations of academic and industry experts. While devising the syllabus content framework, the correct balance between the fundamental / core topics with appropriate mix of topics from the state of the art technologies in electrical and allied domains is attempted. With the increased Industry-Institute interaction and internship programs, students are encouraged to explore the opportunity to improve communication skills, problem solving skill and good team management. These skills shall surely help them to meet the future challenges in their career.

The new course curriculum will also give ample opportunity to the students to work in cross discipline domains to gain the hands on experience through the project based learning facilitated through the various skill based labs, Mini projects, Course projects , Major projects etc. The increased number of department and institute level electives shall facilitate students with the truly choice based learning and skilling in a particular domains.

On behalf of the Board of Studies (BoS) in Electrical Engineering of the University of Mumbai, we seek the active participation from all the stake holders of the engineering education to meet the set outcomes and objectives for the Undergraduate Program in Electrical Engineering.

Board of Studies in Electrical Engineering

Dr. Sushil S. Thale	**: Chairman**
Dr. B. R. Patil	**: Member**
Dr. S. R. Deore	**: Member**
Dr. B. B. Pimple	**: Member**
Dr. Nandkishor Kinhekar	**: Member**

Program Structure for Second Year Electrical Engineering
(Semester III & IV)
UNIVERSITY OF MUMBAI
(With Effect from 2020-2021)

Semester III

Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	Pract.	Tut.	Total
EEC301	Engineering Mathematics-III	3	--	1	3	--	1	4
EEC302	Electrical Circuit Analysis	3		--	3		--	3
EEC303	Fundamentals of Electrical Machines & Measurements	4	--	--	4	--	--	4
EEC304	Electrical Power System I	3	--	--	3	--	--	3
EEC305	Analog Electronics	3	--	--	3	--	--	3
EEL301	Electrical Machines & Measurements Lab	--	2	--	--	1	--	1
EEL302	Electronics Lab-I	--	2	--	--	1	--	1
EEL303	Simulation Lab-I	--	2	--	--	1	--	1
EEL304	SBL-I: Applied Electrical Engineering Lab	--	4	--	--	2	--	2
EEM301	Mini Project – 1A	--	4[$]	--	--	2	--	2
Total		**16**	**14**	**1**	**16**	**07**	**1**	**24**

Examination Scheme

Course Code	Course Name	Theory					Term Work	Pract/ Oral	Total
		Internal Assessment			End Sem. Exam	Exam. Duration (in Hrs)			
		Test I	Test II	Avg					
EEC301	Engineering Mathematics-III	20	20	20	80	3	25	--	125
EEC302	Electrical Circuit Analysis	20	20	20	80	3	--	--	100
EEC303	Fundamentals of Electrical Machines & Measurements	20	20	20	80	3	--	--	100
EEC304	Electrical Power System-I	20	20	20	80	3	--	--	100
EEC305	Analog Electronics	20	20	20	80	3	--	--	100
EEL301	Electrical Machines & Measurements Lab	--	--	--	--	--	25	25	50
EEL302	Electronics Lab-I	--	--	--	--	--	25	25	50
EEL303	Simulation Lab-I	--	--	--	--	--	25	25	50
EEL304	SBL-I: Applied Electrical Engineering Lab	--	--	--	--	--	50	--	50
EEM301	Mini Project – 1A	--	--	--	--	--	25	25	50
Total		**--**	**--**	**100**	**400**	**--**	**175**	**100**	**775**

$ indicates work load of Learner (Not Faculty), for Mini Project

Semester IV

Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	Pract.	Tut.	Total
EEC401	Engineering Mathematics-IV	3	--	1	3	--	1	4
EEC402	Electrical AC Machines-I	3	--	--	3	--	--	3
EEC403	Digital Electronics	3	--	--	3	--	--	3
EEC404	Power Electronic Devices and Circuits	3	--	--	3	--	--	3
EEC405	Electric and Hybrid Electric Vehicles	3	--	--	3	--	--	3
EEL401	Electrical AC Machines Lab I	--	2	--	--	1	--	1
EEL402	Python Programming Lab	--	2	--	--	1	--	1
EEL403	Electronics Lab II	--	2	--	--	1	--	1
EEL404	SBL-II : PCB Design and Fabrication Lab	--	4	--	--	2	--	2
EEM401	Mini Project – 1B	--	4$	--	--	2	--	2
Total		**15**	**14**	**1**	**15**	**7**	**1**	**23**

Examination Scheme

Course Code	Course Name	Theory					Term Work	Pract/ oral	Total
		Internal Assessment			End Sem. Exam.	Exam. Duration (in Hrs)			
		Test I	Test II	Avg.					
EEC401	Engineering Mathematics-IV	20	20	20	80	3	25	--	125
EEC402	Electrical AC Machines-I	20	20	20	80	3	--	--	100
EEC403	Digital Electronics	20	20	20	80	3	--	--	100
EEC404	Power Electronic Devices and Circuits	20	20	20	80	3	--	--	100
EEC405	Electric and Hybrid Electric Vehicles	20	20	20	80	3	--	--	100
EEL401	Electrical AC Machines Lab-I	--	--	--	--	--	25	25	50
EEL402	Python Programming Lab	--	--	--	--	--	25	25	50
EEL403	Electronics Lab-II	--	--	--	--	--	25	25	50
EEL404	SBL-II: PCB Design and Fabrication Lab	--	--	--	--	--	50	--	50
EEM401	Mini Project -1B	--	--	--	--	--	25	25	50
Total		**--**	**--**	**100**	**400**	**--**	**175**	**100**	**775**

$ indicates work load of Learner (Not Faculty), for Mini Project

SBL: Skill Based Lab

Students group and load of faculty per week.

Mini Project 1A / 1B: Students can form groups with minimum 3 (Three) and not more than 4 (Four)
Faculty Load: 1 hour per week per four groups

Semester-III								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEC301	**Engineering Mathematics-III**	**03**	**-**	**01**	**03**	**-**	**01**	**04**

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract.	Oral	
Test-I	Test-II	Average						
20	**20**	**20**	**80**	**03 Hrs**	**25**	**-**	**-**	**125**

Pre-requisite: Engineering Mathematics-I, Engineering Mathematics-II, Scalar and Vector Product: Scalar and vector product of three and four vectors.

Course Objectives	**The course is aimed:** 1. To familiarize with the Laplace Transform, Inverse Laplace Transform of various functions, and its applications. 2. To acquaint with the concept of Fourier Series, its complex form and enhance the problem solving skills 3. To familiarize the concept of complex variables, C-R equations, harmonic functions, its conjugate and mapping in complex plane. 4. To understand the basics of Linear Algebra and its applications 5. To use concepts of vector calculus to analyze and model engineering problems.
Course Outcomes	**On successful completion of course learner/student will be able to:** 1. Apply the concept of Laplace transform to solve the real integrals in engineering problems. 2. Apply the concept of inverse Laplace transform of various functions in engineering problems. 3. Expand the periodic function by using Fourier series for real life problems and complex engineering problems. 4. Find orthogonal trajectories and analytic function by using basic concepts of complex variables. 5. Illustrate the use of matrix algebra to solve the engineering problems. 6. Apply the concepts of vector calculus in real life problems.

Module	Detailed Contents	Hours
1.	**Module: Laplace Transform** 1.1 Definition of Laplace transform, Condition of Existence of Laplace transform. 1.2 Laplace Transform (L) of Standard Functions like e^{at}, $sin(at)$, $cos(at)$, $sinh(at)$, $cosh(at)$ and $t^n, n \geq 0$. 1.3 Properties of Laplace Transform: Linearity, First Shifting theorem, Second Shifting Theorem, change of scale Property, multiplication by *t*, Division by *t,* Laplace Transform of derivatives and integrals (Properties without proof). 1.4 Evaluation of integrals by using Laplace Transformation. **Self-learning Topics:** Heaviside's Unit Step function, Laplace Transform of Periodic functions, Dirac Delta Function.	**07**

2.	**Module: Inverse Laplace Transform** 2.1 Inverse Laplace Transform, Linearity property, use of standard formulae to find inverse Laplace Transform, finding Inverse Laplace transform using derivatives. 2.2 Partial fractions method to find inverse Laplace transform. 2.3 Inverse Laplace transform using Convolution theorem (without proof). **Self-learning Topics:** Applications to solve initial and boundary value problems involving ordinary differential equations.	**06**
3.	**Module: Fourier Series:** 3.1 Dirichlet's conditions, Definition of Fourier series and Parseval's Identity (without proof). 3.2 Fourier series of periodic function with period 2π and $2l$. 3.3 Fourier series of even and odd functions. 3.4 Half range Sine and Cosine Series. **Self-learning Topics:** Complex form of Fourier Series, Orthogonal and orthonormal set of functions. Fourier Transform.	**07**
4.	**Module: Complex Variables:** 4.1 Function $f(z)$ of complex variable, limit, continuity and differentiability of $f(z)$Analytic function, necessary and sufficient conditions for $f(z)$ to be analytic (without proof). 4.2 Cauchy-Riemann equations in cartesian coordinates (without proof). 4.3 Milne-Thomson method to determine analytic function $f(z)$when real part (u) or Imaginary part (v) or its combination (u+v or u-v) is given. 4.4 Harmonic function, Harmonic conjugate and orthogonal trajectories **Self-learning Topics:** Conformal mapping, linear, bilinear mapping, cross ratio, fixed points and standard transformations.	**07**
5.	**Module: Linear Algebra: Matrix Theory** 5.1 Characteristic equation, Eigen values and Eigen vectors, Example based on properties of Eigen values and Eigen vectors. (Without Proof). 5.2 Cayley-Hamilton theorem (Without proof), Examples based on verification of Cayley- Hamilton theorem and compute inverse of Matrix. 5.3 Similarity of matrices, Diagonalization of matrices. Functions of square matrix **Self-learning Topics:** Application of Matrix Theory in machine learning and google page rank algorithms, derogatory and non-derogatory matrices**.**	**06**
6.	**Module: Vector Differentiation and Integra**l 6.1 **Vector differentiation**: Basics of Gradient, Divergence and Curl (Without Proof) 6.2 **Properties of vector field:** Solenoidal and irrotational (conservative) vector fields 6.3 **Vector integral:** Line Integral, Green's theorem in a plane (Without Proof), Stokes' theorem (Without Proof) only evaluation. **Self-learning Topics:** Gauss' divergence Theorem and applications of Vector calculus.	**06**

Term Work:

General Instructions:

1. Students must be encouraged to write at least 6 class tutorials on entire syllabus.
2. A group of 4-6 students should be assigned a self-learning topic. Students should prepare a presentation/problem solving of 10-15 minutes. This should be considered as mini project in

Engineering Mathematics. This project should be graded for 10 marks depending on the performance of the students.

The distribution of Term Work marks will be as follows –

1.	Attendance (Theory and Tutorial)	05 marks
2.	Class Tutorials on entire syllabus	10 marks
3.	Mini project	10 marks

Assessment:

Internal Assessment Test:

Assessment consists of two class tests of 20 marks each. The first class test (Internal Assessment-I) is to be conducted when approx. 40% syllabus is completed and second class test (Internal Assessment-II) when additional 40% (approx.) syllabus is completed. Duration of each test shall be one hour.

End Semester Theory Examination:

1. Question paper will comprise of total 06 questions, each carrying 20 marks.
2. Total 04 questions need to be solved.
3. Question No: 01 will be compulsory and based on entire syllabus wherein 4 sub-questions of 5 marks each will be asked.
4. Remaining questions will be randomly selected from all the modules.
5. Weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

References Books:

1. Advanced engineering mathematics, H.K. Das, S. Chand, Publications
2. Higher Engineering Mathematics, B. V. Ramana, Tata Mc-Graw Hill Publication
3. Advanced Engineering Mathematics, R. K. Jain and S. R. K. Iyengar, Narosa publication
4. Advanced Engineering Mathematics, Wylie and Barret, Tata Mc-Graw Hill.
5. Theory and Problems of Fourier Analysis with applications to BVP, Murray Spiegel, Schaum's Outline Series
6. Vector Analysis Murry R. Spiegel, Schaum's outline series, Mc-Graw Hill Publication
7. Beginning Linear Algebra, Seymour Lipschutz, Schaum's outline series, Mc-Graw Hill Publication
8. Higher Engineering Mathematics, Dr. B. S. Grewal, Khanna Publication

Semester-III								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEC302	**Electrical Circuit Analysis**	**03**	**-**	**-**	**03**	**-**	**-**	**03**

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract.	Oral	
Test-I	Test-II	Average						
20	**20**	**20**	**80**	**03 Hrs**	**-**	**-**	**-**	**100**

Course Objectives	**The course is aimed:** 1. To impart the knowledge of various fundamental electrical theorems for analysis of electrical circuits from application point of view. 2. To inculcate the problem solving and analysis skills in students.
Course Outcomes	**Upon successful completion of this course, the learner will be able to** 1. Apply network theorems for the analysis of electrical circuits. 2. Obtain the transient and steady-state response of electrical circuits. 3. Develop and analyse transfer function model of system using two port network parameters. 4. Analyse time domain behaviour from pole zero plot. 5. Analyse electrical network using graph theory. 6. Analyse the effect of switching conditions on electrical networks using differential equations and Laplace Theorem.

Module	Detailed Contents	Hours
1.	**Electrical Circuit Analysis** **With DC Dependent Sources:** Mesh analysis, Super mesh analysis, Nodal analysis, Super node analysis, Source transformation and Source shifting. Superposition theorem, Thevenin's theorems and Norton's theorem and Maximum power transfer theorem; **With AC Sources:** Magnetic coupling, Mesh analysis, Nodal analysis, Superposition theorem, Thevenin's theorems, Norton's theorem, Maximum power transfer theorem and Reciprocity theorem.	**09**
2.	**First and Second Order Circuits:** Solution of first and second order differential equations for Series and parallel R-L, R-C, R-L-C circuits, initial and final conditions in network elements, forced and free response, time constants, steady state and transient state response.	**06**
3.	**Graph Theory and Network Topology:** Introduction, Graph of network, Tree, Co-tree, Loop incidence matrix, Cut set matrix, Tie set matrix and Loop current matrix, Number of possible tree of a graph, Analysis of network equilibrium equation and Principle of duality.	**06**
4.	**Electrical Circuit Analysis Using Laplace Transforms:** The Laplace transform and its application in electrical circuit analysis, transient and steady state response to step, ramp and impulse signals.	**06**

5.	**Two port parameters:** Open circuit, short circuit, transmission and hybrid Parameters, relationships between parameter sets, reciprocity and symmetry conditions, parallel connection of two port networks, cascade connection of two-port networks.	**06**
6.	**Network Functions- Poles and Zeros:** Network functions for one port and two port networks, Driving point and transfer functions, ladder network, General network, poles and zeros of network functions, restrictions on Pole and zero locations for driving point functions and Transfer functions, time domain behavior from pole - zero plot.	**06**

Assessment:

Internal Assessment Test:

Assessment consists of two class tests of 20 marks each. The first class test (Internal Assessment-TEST-I) is to be conducted when approx. 40% syllabus is completed and second class test (Internal Assessment Test-II) when additional 40% syllabus is completed. Duration of each test shall be one hour.

End Semester Theory Examination:

1. Question paper will comprise of total 06 questions, each carrying 20 marks.
2. Total 04 questions need to be solved.
3. Question No.1 will be compulsory and based on entire syllabus wherein 4 sub-questions of 5 marks each will be asked.
4. Remaining questions will be randomly selected from all the modules.
5. Weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

Books Recommended:

Text Books:

1. W H Hayt, S M Durbin, J E Kemmerly, *Engineering Circuit Analysis,* Tata McGraw-Hill Education, 2013.
2. M. E. Van Valkenburg, *Network Analysis,* 3rd Edition, PHI Learning.
3. D. Roy Choudhury, *Networks and System,* 2nd Edition, New Age International.
4. M. E. Van Valkenburg, *Linear Circuits*, Prentice Hall.
5. C. K. Alexander and M. N. O. Sadiku, *Electric Circuits*, McGraw Hill Education, 2004.
6. K. V. V. Murthy and M. S. Kamath, *Basic Circuit Analysis*, Jaico Publishers, 1999

Reference Books:

1. F. F. Kuo, *Network Analysis and Synthesis*, John Wiley and sons.
2. N Balabanian and T.A. Bickart, *Linear Network Theory: Analysis, Properties, Design and Synthesis*, Matrix Publishers.
3. C. L.Wadhwa, *Network Analysis and Synthesis*, New Age International.
4. B. Somanathan Nair, *Network Analysis and Synthesis*, Elsevier Publications.

NPTEL/ Swayam Course:

1. **Course: Basic Electric Circuits By Prof. Ankush Sharma (IIT Kanpur); https://swayam.gov.in/nd1_noc19_ee36/preview**
2. **Course: Basic Electrical Circuits by Prof. Nagendra Krishnapura (IIT Madras) https://nptel.ac.in/noc/courses/noc20/SEM2/noc20-ee64/**

Semester-III								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEC303	**Fundamentals of Electrical Machines & Measurements**	**04**	**-**	**-**	**04**	**-**	**-**	**04**

Examination Scheme								
Theory					Term Work/Practical/Oral			Total
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract.	Oral	
Test-I	Test-II	Average						
20	**20**	**20**	**80**	**03 Hrs**	**-**	**-**	**-**	**100**

Course Objectives	**The course is aimed:** 1. To study the concepts of magnetism and energy conversion. 2. To familiarize with the operational characteristics of DC machines and their applications. 3. To learn the working principles of various analog and digital instruments & devices used for measurement of the various electrical and electronic parameters.
Course Outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Illustrate the principle of energy conversion in single and double excited machines. 2. Understand and analyze the significance of the DC machines performance parameters. 3. Implement various starting methods and speed control methods for DC machines applications 4. Evaluate the working of various sensors, transducers and analog / digital instruments used in electrical and electronic measurements. 5. Analyze the use and performance of bridges used in electrical and electronic measurements. 6. Illustrate the need for extension of range of meters and calibration in instruments.

Module	Detailed Contents	Hours
1	**Basics of Magnetism:** Magnetic field and circuit, Numerical based on series parallel magnetic circuit, Flux linkage, Inductance and energy, Faraday's laws, Hysteresis and eddy current losses.	**05**
2	**Electromechanical Energy Conversion:** Principle, Energy stored in magnetic field, Field and co energy, Force and torque equations, Torque in singly and doubly excited systems, MMF in distributed windings Winding inductance, Magnetic field in rotating machines, Rotating MMF wave Leakage flux and magnetic saturation.	**09**
3	**DC Machines:** Review of construction and components of DC machine, commutator and brushes, concept of back EMF, and torque equations, Types of DC machines; Armature reaction, Characteristics of DC generators and motors (speed – torque and performance), Necessity of starter and types, Speed control and braking methods, Losses and efficiency, Swinburne's, Hopkinson's and Retardation tests; PMDC motor.	**12**

4	**Analog Measurement:** Fundamental element of an instrument, Static and dynamic characteristics, Errors in Measurement, Standards and calibrations, Difference between indicating and integrating instruments, Moving coil and moving iron instruments, Ammeters shunts & voltmeter multiplier, Dynamometer type wattmeter, Power factor meter, Instrument transformer. Measurements of R, L and C.	**08**
5	**Potentiometers, Bridges and Transducers:** **Potentiometers:** Basic potentiometer circuit, calibration of ammeter, voltmeter and wattmeter. **Bridges:** Wheatstone, Kelvin's double bridge, Maxwell's bridge, Schering Bridge, Q meter. **Transducers:** Classification of transducers, Selection of transducers, Resistive, capacitive & inductive transducers, Piezoelectric, Hall effect, Optical and digital transducers. **Measurement of non-electrical quantities:** Basic principles of: temperature (Thermistor and Thermo couple), pressure (strain-gauge, capacitive and inductive type) and speed (Inductive and Hall Effect). Basic requirements of signal conditioning circuits. Amplifier, Filter, and linearization circuit. **Self-study**: Hay's bridge, Anderson's bridge, velocity, force and torque measurement.	**10**
6	**Digital Measurements:** Advantages of digital meters over analog meters, Resolution & sensitivity of digital meters, Working principles of digital Voltmeter, Ammeter, Multi-meter. Working principles and features of Digital Tachometer, Digital Megger, and Digital Storage Oscilloscope. Introduction to MEMS (micro-electromechanical systems) technology and their applications in electrical and automotive domain.	**08**

Assessment:

Internal Assessment Test:

Assessment consists of two class tests of 20 marks each. The first class test (Internal Assessment-I) is to be conducted when approx. 40% syllabus is completed and second class test (Internal Assessment-II) when additional 40% (approx.) syllabus is completed. Duration of each test shall be one hour.

End Semester Theory Examination:

1. Question paper will comprise of total 06 questions, each carrying 20 marks.
2. Total 04 questions need to be solved.
3. Question No: 01 will be compulsory and based on entire syllabus wherein 4 sub-questions of 5 marks each will be asked.
4. Remaining questions will be randomly selected from all the modules.
5. Weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

Books Recommended:

Text Books:

1. Bimbhra P. S., *Electric Machinery*, Khanna Publisher,
2. Bimbhra P. S., *Generalized Machine Theory*, Khanna Publisher,
3. S. K. Pillai, *A first course on Electrical Drives,* New Age Publication
4. V. K. Mehta, *Principles of Electrical Machines,* S Chand Publications
5. AK Sawhney, *Electrical & Electronic Measurements and Instrumentation*, Dhanpat Rai & Sons
6. Helfric and Cooper, *Modern Electronic Instrumentation and Measurement Techniques*, PHI
7. H.S.Kalsi, *Electronic Instrumentation*, Third Edition, Tata McGraw Hill

8. Ramon Pallaá S-Areny and J. G. Webster, *Sensors And Signal Conditioning*, Second Edition, John Wiley & Sons, Inc.

Reference Books:

1. M. G. Say and E. O. Taylor, *Direct current machines*, Pitman publication
2. Ashfaq Husain, *Electric Machines*, Dhanpat Rai and Co. Publications
3. Alan.S.Moris, *Principle of Measurement & Instrumentation*, Prentice Hall of India
4. RS Sirohi & Radhakrisnan, *Electrical Measurement & Instrumentation*, New Age International
5. M. V. Deshpande, *Electric Machines*, PHI
6. Vedam Subramanyam, *Electrical Drive-concept and applications*, TMH Publication
7. Sabrie Soloman, *Sensors Handbook*, Second Edition, McGraw Hill

NPTEL/ Swayam Course:

Course: Electrical Machines – I By Prof. Tapas Kumar Bhattacharya (IIT Kharagpur)
https://swayam.gov.in/nd1_noc20_ee60/preview

Semester-III								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEC304	**Electrical Power System-I**	**03**	**-**	**-**	**03**	**-**	**-**	**03**

Examination Scheme								
Theory					Term Work/Practical/Oral			Total
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract.	Oral	
Test-I	Test-II	Average						
20	**20**	**20**	**80**	**03 Hrs**	**-**	**-**	**-**	**100**

Course Objectives	**The course is aimed:** 1. To learn basics of electrical power systems and its different components. 2. To acquaint knowledge of transmission / distribution line and its parameters. 3. To learn representation and performance evaluation of power systems. 4. To understand electric cable and earthing
Course Outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Understand the power system and its components. 2. Categorize the ac transmission / distribution lines and understand the insulators. 3. Evaluate the parameters of different types of ac transmission / distribution lines. 4. Draw the PU reactance diagram of a power system for analysis. 5. Analyse the performance of transmission lines. 6. Study the performance parameters of electric cable and earthing.

Module	Detailed Contents	Hours
1	**Introduction:** Basic structure of power system: generation, transmission and distribution, single line diagram of typical AC supply system, different types of conventional and non-conventional energy sources, their working principle and operation with block diagram.	**06**
2	**Types of AC Transmission / Distribution Lines and Insulators:** **Types of AC Transmission / Distribution Lines:** single phase two wire, three phase three wire (symmetrical and unsymmetrical spacing), three phase double circuit, three phase four wire, concept of composite and bundle conductor. **Insulators:** Type of insulators, potential distribution across insulator string, string efficiency, methods for improving string efficiency (Numerical).	**06**
3	**Transmission / Distribution Line Parameters:** Resistance of transmission line, skin effect, proximity effect, definition of inductance, internal and external flux linkage of single conductor, inductance of single phase two wire line, inductance of three phase three wire line with symmetrical and unsymmetrical spacing, concept of GMR and GMD, inductance of three phase double circuit line, inductance of bundled conductor lines, Capacitance of transmission line, capacitance of single phase line, capacitance of three phase line with symmetrical and unsymmetrical spacing, effect of earth on transmission line capacitance (single phase only) (Numerical)	**10**

4	**Representation of Power System Components:** Introduction, single phase solution of balanced three phase networks, one-line diagram and impedance or reactance diagram, Per Unit (PU) system, advantage of PU system, PU impedance diagram, representation of load (Numerical).	**05**
5	**Performance of Transmission Line:** Classification and modelling of short, medium and long lines, regulation and efficiency of short and medium lines, Ferranti effect, evaluation and estimation of generalized circuit constant (ABCD) for short and medium lines, surge impedance loading, tuned power line, (Numerical).	**06**
6	**Electric Cable and Earthing:** **Electric Cable:** Classification and construction of cable, insulation resistance of cable, capacitance of single core and three core cable, grading of cable, inter-sheath grading, capacitance grading **Earthing:** Earthing definition, soil resistivity, step and touch potentials; measurement of earth resistance, soil resistivity, neutral grounding and its methods.	**06**

Assessment:

Internal Assessment Test:

Assessment consists of two class tests of 20 marks each. The first class test (Internal Assessment-I) is to be conducted when approx. 40% syllabus is completed and second class test (Internal Assessment-II) when additional 40% (approx.) syllabus is completed. Duration of each test shall be one hour.

End Semester Theory Examination:

1. Question paper will comprise of total 06 questions, each carrying 20 marks.
2. Total 04 questions need to be solved.
3. Question No: 01 will be compulsory and based on entire syllabus wherein 4 sub-questions of 5 marks each will be asked.
4. Remaining questions will be randomly selected from all the modules.
5. Weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

Books Recommended:

Text Books:

1. Fredrick T Morse*, Power Plant Engineering,* East-West Press Pvt Ltd
2. Mahesh Verma*, Power Plant Engineering,* Metrolitan Book Co Pvt Ltd
3. RK Rajput*, A Text Book of Power System engineering,* Laxmi Publication
4. George W Sutton-(Editor)*, Direct Energy Conversion,* Lathur University, Electronic Series Vol-3 McGraw Hill
5. D. P. Kothari, I. J. Nagrath, *Power System Engineering*, 3 Edition, Mc Graw Hill
6. B.R. Gupta, *Power System Analysis And Design*, S.Chand
7. J B. Gupta, *A Course in Power System*, S. K. Kataria & Sons
8. Mehta V.K., *Principles of Power System*, S Chand

Reference Books:-

1. Stevenson and Grainger, *Modern Power System Analysis*, 1 Edition, TMH publication
2. W. D. Stevenson, *Elements of Power System*, 4 Edition TMH

NPTEL/ Swayam Course:

Course: **Power System Analysis, By Prof. Debapriya Das (IIT Kharagpur)**
https://swayam.gov.in/nd1_noc19_ee62/preview

Semester-III								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEC305	**Analog Electronics**	**03**	**-**	**-**	**03**	**-**	**-**	**03**

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract.	Oral	
Test-I	Test-II	Average						
20	**20**	**20**	**80**	**03 Hrs**	**-**	**-**	**-**	**100**

Course Objectives	**The course is aimed:** 1. To understand the characteristics of diode, transistors and FETs. 2. To understand design of different biasing circuits of BJT and MOSFET. 3. To understand the functioning of Op-Amplifier and design of Op- amp based circuits. 4. To understand the functioning of linear voltage regulators and IC 555.
Course Outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Analyze the performance of various rectifiers and filter circuits. 2. Illustrate the use DC and AC parameters of BJT in analysis of amplifier circuits. 3. Apply the knowledge of MOSFET's DC/ AC parameters in analysis of amplifier and switching applications of MOSFET. 4. Understand the functioning of OP-AMP and design OP-AMP based circuits. 5. Illustrate the practical design aspect of regulated power supply circuits using linear regulators. 6. Understand applications of commonly used special semiconductor devices.

Module	Detailed Contents	Hours
1	**Diode:** Basic construction, Operation and characteristics of diode, Application of diode as clipper, Full Wave Bridge Rectifier with and without Filter; analysis and selection of the components required for C and LC filter (Numerical).	**05**
2	**Bipolar Junction Transistor:** Structure and I-V characteristics of a BJT; BJT as a switch. BJT as an amplifier *DC Circuit Analysis:* Types of biasing circuits, load line (Numerical); thermal runaway, stability factor analysis, thermal stabilization. *AC Circuit Analysis:* Small signal analysis of CE configurations with different biasing network using H-parameter Model and r_e Model. Amplification derivation of expression for voltage gain, current gain, input impedance and output impedance of CC, CE amplifiers (Numerical); Study of frequency response of BJT amplifier. Introduction BJT's hybrid-pi model.	**08**
3	**Field Effect Transistor:** Types of FETs, basics of construction and working principle; MOSFET structure and I-V characteristics. MOSFET as a switch. MOSFET as an amplifier *DC Circuit Analysis*: Types of biasing circuits of MOSFET (Numerical), dc load line and region of operation. *AC Circuit Analysis*: Small signal model of MOSFET CS amplifier, derivation of expressions for voltage gain and output impedance of MOSFET CS amplifier (Numerical).	**07**

4	**Operational Amplifiers:** Differential amplifier, direct coupled multi-stage amplifier, Block diagram of Op-amp, ideal op-amp, non-idealities in an op-amp, Frequency response; Idealized analysis and design of Inverting and Non-inverting amplifier, voltage follower; Design of different Op-amp circuits (adder, subtractor, integrator and differentiator, Schmitt trigger)(with Numerical); Comparator (ZCD, window comparator); introduction to Instrumentation amplifier (using 3 Op-amp); First order Low Pass Filter using op-amp; Oscillator (Wein bridge), Square-wave generator.	**10**
5	**Linear Voltage Regulators and Timer:** IC-78xx, 79xx, LM 317, Design of voltage supply using IC-78xx and LM317 (Numerical). IC-555- Functional block diagram, study of Mono-stable and Astable Multivibrator using IC555 (Numerical)	**05**
6	**Special Purpose Semiconductor Devices:** Principle of operation and applications of special diodes– Zener diode, LED, Schottky diode and Photodiode; Basics of Opto-isolator.	**04**

Assessment:

Internal Assessment Test:

Assessment consists of two class tests of 20 marks each. The first class test (Internal Assessment-I) is to be conducted when approx. 40% syllabus is completed and second class test (Internal Assessment-II) when additional 40% (approx.) syllabus is completed. Duration of each test shall be one hour.

End Semester Theory Examination:

1. Question paper will comprise of total 06 questions, each carrying 20 marks.
2. Total 04 questions need to be solved.
3. Question No: 01 will be compulsory and based on entire syllabus wherein 4 sub-questions of 5 marks each will be asked.
4. Remaining questions will be randomly selected from all the modules.
5. Weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

Books Recommended:

Text Books:-

1. Neamen D.A., *Electronic Circuit Analysis and Design*, McGraw Hill International.
2. Robert Boylestad and Louis Nashelsky, *Electronic Devices and Circuits*, PHI
3. Ramakant A. Gayakwad, *Op-Amps and Linear Integrated Circuits*, PHI, 2000
4. Millman and Halkias, *Electronic Devices and Circuits*, Tata McGraw-Hill.
5. A. S. Sedra and K. C. Smith, *Micro-electronic Circuits*, Oxford University Press, 1998.

Reference Books:-

1. David Bell, *Electronic Devices and Circuits*, Oxford University Press
2. Thomas Floyd, *Electronic Devices*, PHI
3. S. Salivahanan and N. Suresh Kumar, "*Electronic Devices and Circuits, TMH*
4. P. Horowitz and W. Hill, *The Art of Electronics,* Cambridge University Press, 3rd Edition

NPTEL/ Swayam Course:

1. **Course**: **Analog Electronic Circuits By Prof. Pradip Mandal (IIT Kharagpur)**
   https://swayam.gov.in/nd1_noc20_ee45/preview
2. **Course: Analog Electronic Circuit By Prof. Shouribrata Chatterjee (IIT Madras)**
   https://nptel.ac.in/noc/courses/noc20/SEM2/noc20-ee89/

Semester-III								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEL301	**Electrical Machines and Measurements Lab**	-	**02**	**-**	**-**	**01**	**-**	**01**

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract./ Oral	Oral	
Test-I	Test-II	Average						
-	**-**	**-**	**-**	**-**	**25**	**-**	**25**	**50**

Course Objectives	**To impart the knowledge on the following :** 1. Practical understanding of DC machines and their applications. 2. Working principles of various sensors, transducers and instruments used for measurement of the various physical parameters.
Course Outcomes	**Upon successful completion of this course, the learner will be able to** 1. Illustrate and analyze the performance of DC machines. 2. Demonstrate different speed control methods of DC motors. 3. Illustrate and analyze the working of various sensors, transducers and instruments used for measurement of the various physical parameters. 4. Demonstrate the use of bridges for measurements of passive electrical components. 5. Understand and analyse the working signal processing circuits used in measurements and instruments

Syllabus: Same as **EEC303: Fundamentals of Electrical Machines and Measurements**

Suggested List of Laboratory Experiments: Minimum four from 1 – 9 and four from 10 – 16, in all minimum eight experiments need to be performed.

1. Open circuit and load characteristics of DC shunt generator.
2. Load characteristics of DC compound generator with differential and cumulative connections.
3. Load test on DC shunt motor.
4. Load test on DC compound motor.
5. Load test on DC series motor.
6. Speed control of DC shunt motor.
7. Retardation test of DC motor.
8. Swinburne's test on DC motor.
9. Hopkinson's test on DC motor.
10. Measurement of the medium resistance using Wheatstone bridge.
11. Measurement of the low resistance using Kelvin’s double bridge.
12. Measurement of inductance using Maxwell’s bridge.
13. Measurement of capacitance using Schering’s bridge.
14. Measurement of R/L/C using a bridge technique as well as LCR meter.
15. Current Measurement using Shunt, CT, and Hall Sensor.
16. Measurement of temperature using RTD/ Thermistor
17. Measurement of Pressure using Pressure transducer.
18. Study of Signal Processing circuits used for sensors/ transducers.
19. Range Extension of meters used in electrical and electronic measurements.

Any other experiments based on syllabus which will help students to understand topic/concept.

Note:

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

Virtual Lab Website Reference

1. http://vlab.co.in/broad-area-electrical-engineering
2. http://vlab.co.in/broad-area-electronics-and-communications

Term work:

Term work shall consist of minimum 08 experiments. The distribution of marks for term work shall be as follows:

Laboratory Performance	: 10 marks
Journal	: 10 marks
Attendance	: 05 marks

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

Oral Examination:

Oral examination will be based on entire syllabus of **EEC303: Fundamentals of Electrical Machines & Measurements**

Semester-III								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEL302	**Electronics Lab-I**	-	**02**	**-**	**-**	**01**	**-**	**01**

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract./ Oral	Oral	
Test-I	Test-II	Average						
-	**-**	**-**	**-**	**-**	**25**	**25**	**-**	**50**

Course Objectives	**The course is aimed:** 1. To understand the basic concept of various electronic devices, circuits and their application. 2. To develop ability among students to design and implement electronic circuits.
Course Outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Identify the different types of semiconductor devices and demonstrate their applications in electronic circuits. 2. Analyse the performance of different types of rectifier with and without filter. 3. Determine the dc and ac parameters of various semiconductor devices. 4. Illustrate the frequency response of BJT/ MOSFET amplifier. 5. Understand the practical use of Op-amps in signal processing and waveform generators.

Syllabus: Same as that of Course **EEC305 Analog Electronics**

Suggested List of Laboratory Experiments: Minimum eight experiments need to be performed.

1. Study of V-I characteristics of standard PN junction diode.
2. Use of diode as clipper.
3. Rectifier- Filter performance analysis
4. BJT biasing network and stability analysis
5. BJT Input and Output Characteristics for CE configuration
6. Frequency response of BJT CE amplifier
7. Study of MOSFET characteristics and calculation of parameters
8. Frequency response of MOSFET CS amplifier
9. Study of differential BJT amplifier
10. Design of OP-AMP based Inverting amplifier and Non-inverting Amplifier
11. Study of OP-AMP as Adder and Subtractor
12. Study of OP-AMP as comparator
13. Study of a OP-AMP based Wien Bridge oscillator
14. Design of adjustable Voltage regulator based on IC 78XX
15. Design of adjustable Voltage regulator based on LM317
16. Study of V-I characteristics of zener diode.
17. Study of V-I characteristics of Schottkey diode.
18. Study of photo devices applications
19. Study of opto-isolators

Any other experiment based on syllabus which will help students to understand topic/concept.

Note:

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

Virtual Lab Website Reference

1. http://vlab.co.in/broad-area-electrical-engineering
2. http://vlab.co.in/broad-area-electronics-and-communications

Term work:

Term work shall consist of minimum 08 experiments. The distribution of marks for term work shall be as follows:

Laboratory Performance	: 10 marks
Journal	: 10 marks
Attendance	: 05 marks

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

Practical & Oral Examination:

Practical exam will be based on all the experiments carried out & Oral examination will be based on entire syllabus of **EEC305 Analog Electronics.**
The distribution of marks for practical/ oral examination shall be as follows:

- Practical Exam : 15 marks
- Oral Exam : 10 marks

Semester-III								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEL303	**Simulation Lab-I**	-	**02**	**-**	**-**	**01**	**-**	**01**

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract./ Oral	Oral	
Test-I	Test-II	Average						
-	**-**	**-**	**-**	**-**	**25**	**-**	**25**	**50**

Course Objectives	**The course is aimed:** 1. To understand basic block sets of different simulation platform used in electrical /electronic circuit design. 2. To understand use and coding in different software tools used in electrical/ electronic circuit design
Course Outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Develop the skill to use the software packages to model and program electrical and electronics systems 2. Model different electrical and electronic systems and analyze the results 3. Articulate importance of software packages used for simulation in laboratory experimentation /research/industry by analyzing the simulation results. 4. Simulate electric machines/circuits for performance analysis.

Suggested Software Tools to be Used for Simulation Lab-I:

1. Students should be encouraged to use open source softwares such as **SCILAB, LTSPICE**, Texas Instrument's '**Webbench**', **Ngspice,** ***Solve Elec*** etc. for carrying out the lab simulation listed below.
2. Use of Professional Licensed versions of softwares like **MATLAB**, **Proteus**, **LabVIEW**, **NI Multisim, PSpice, PowerSim, TINA** etc. is also allowed**.**
3. Use of 'Python' platform for simulating components/ circuit behaviour.

Suggested List of Laboratory Experiment: Minimum eight experiments need to be performed from various subjects domain

1. Introduction to basic block sets of simulation platform.
2. Simulation of single phase bridge rectifier with and without filter
3. Algorithm on matrix operations
4. Simulation of transmission line model
5. Algorithms to determine transmission line performance and parameters
6. Simulation of differential equations
7. Simulation to verify different network theorems with dependent and independent sources
8. Algorithm for generation of standard test signals
9. Simulation / Algorithms to draw the response of electrical network for standard test signals.
10. Simulation / Algorithms to draw the pole zero plot of electrical networks
11. Simulation of DC motor performance characteristics
12. Simulation of various measurement bridges l Maxwell's bridge, Hay's bridge etc.
13. Design of OP-AMP based Inverting amplifier and Non-inverting Amplifier

14. Study of OP-AMP as Adder and Subtractor
15. Study of OP-AMP as comparator
16. Study of a OP-AMP based RC phase shift oscillator
17. Study of a OP-AMP based Wien Bridge oscillator

Any other simulations / algorithms based on third semester syllabus, which will help students to understand topic / concept.

Note:

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

Virtual Lab Website Reference:

1. http://vlab.co.in/broad-area-electrical-engineering
2. http://vlab.co.in/broad-area-electronics-and-communications

Term work:
Term work consists of minimum 08 simulation / algorithms from various subject domains. The distribution of the term work shall be as follows:

Simulation / Algorithm	: 20 marks
Attendance	: 05 marks

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

Oral Examination:
Oral examination will be based on all the laboratory experiments carried out in **Simulation Lab-I**

Semester-III								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEL304	**Skill Based Lab (SBL-I) Applied Electrical Engineering Lab**	-	**04**	**-**	**-**	**02**	**-**	**02**

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract./ Oral	Oral	
Test-I	Test-II	Average						
-	**-**	**-**	**-**	**-**	**50**	**-**	**-**	**50**

Course Objectives	**The course is aimed:** 1. To provide hands on experience to use laboratory instruments for testing and measurement. 2. To develop the ability to repair and maintain electrical equipment/ appliances 3. To impart the knowledge of electrical installation on institute campus. 4. To impart the knowledge of Electrical fire and shock hazards safety.
Course Outcomes	**Upon successful completion of this course, the learner will be able to** 1. Demonstrate the effective use of various electrical and electronic measuring lab equipments. 2. Identify various electrical LV/HV substation, supply equipments and their network connection 3. Identify and use different low voltage protective switchgears along with residential / industrial wiring practices. 4. Illustrate the understanding of Repair and maintenance of common electrical appliances. 5. Handle Electrical fire and shock hazards safety challenges in real practice.

Module	Detailed Contents	Hours
1	**Use of Lab Equipments:** *Standard Lab Equipments*: Multi-meter, Power Supply, Function Generator, Tachometer, thermometer, clamp-on meter, DSO etc. (**Study all the equipments**) *Special Measuring Equipments*: True RMS multi-meter, Lux meter, Megger, LCRQ meter, Power Meter, Thermal Analyser, Anemometer, Humidity Meter, Earthing Resistance meter, Insulation Resistance meter etc. (**Study at least 3 such equipments**) *Special Lab Equipments:* High Power DC Supply, Isolated DSO, Power Analyser, Emulators etc. (**Study at least one of such equipments**) **Lab Activities**: Students should be trained to use these classes of lab equipments with good expertise achieved. Students should clearly understand and differentiate the situations in which use of each of these equipments is best suitable.	**12**
2	**Electrical LV/HV Substation and Supply Equipments:** Electrical LV/HV Substation: RMU, Transformer, HV switchgear and panels, LV switchgears and panels, HT metering, LT metering APFC panel, Backup DG sets, UPS, Changeover switchgears, Feeder Pillar, Solar PV Installation. Single line diagram (SLD), Supply Utility service: Electricity bills and details. **Students should study the actual electrical supply system on institute campus, prepare SLD for the network and detailed report on actual ratings of the complete system.**	**06**

3	**Residential/ Industrial Wiring and switch-gears** Wiring materials, selection of wire, conductor sizing, Cables and cable management Estimation and costing of residential wiring (**Simple numerical on wiring of single room**); Fire retardant wires. Different switching and protection devices (MCBs/ Fuses/Relays), selection and sizing connection of energy meter and distribution board, wiring standards (IS-732, section 4). (**Students should be given demonstration of real life devices and DBs in use**). **Students should perform following experiments (Any three)** 1. Identify different types of cables/wires, switches and their uses. 2. Identify different types of fuses & fuse carriers, MCB and ELCB, MCCB with ratings and usage. 5. Wiring of simple light circuit for controlling light/fan point (PVC conduit wiring and wiring accessories) 6. Wiring of fluorescent lamps and light sockets (6 A). 7. Wiring of Power circuit for controlling power device (16A socket) 8. Design of Staircase wiring / Go-down wiring / Tunnel wiring 9. Demonstration and measurement of power/energy consumption and repair maintenance of electric iron/mixer grinder/ washing machine/refrigerator/ air conditioner/water heater/geyser/single phase pump/exhaust fan.	**12**
4	**Repair and Maintenance of House-hold Appliances and Machines:** Testing, fault finding, Dismantling, assembling and testing after repairs of house hold appliances like standard fan and regulator, BLDC fan, heater, geyser, mixer, washing machine, microwave oven, LED lamps/tubes, Induction Cooker, Air cooler etc. (**Minimum three such appliances must be studied**) Troubleshooting of 1 ph and 3ph transformers and motors (**Minimum one transformer and one motor**)	**12**
5	**Electrical Fire Prevention and Safety in Buildings:** Guidelines and charts for electrical fire prevention, role of electrical switchgear and protection devices, Earth leakage and Earth Resistance measurements, Preventive maintenance, Thermal analysis of electrical installations, Electrical Fire mitigation ; Electrical Shock safety, symptoms and emergency first aid; Indian Electricity Act and National Electrical Code; (**Complete training of Electrical Fire Prevention and Safety must be provided to all the students)**	**10**

Term Work:

Term work shall consist of minimum requirement as given in the syllabus. The distribution of marks for term work shall be as follows:

Laboratory Performance : 30 marks
Journal : 10 marks
Attendance : 10 marks

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

Books Recommended:

1. J. B. Gupta, *Electrical Installation Estimating & Costing,* S. K. Kataria & Sons, 2009
2. Raina Bhattachraya, *Electrical Design Estimating And Costing,* New Age International,
3. K B. Bhatia, *Electrical Appliances and Devices,* Khanna Publications
4. K B. Bhatia, *Fundamentals of Maintenance of Electrical Equipments,* Khanna Publications
5. BIS SP 30:National Electrical Code
6. Electricity Act 2003

Semester-III								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEM301	**Mini Project – 1A**	-	**04$**	**-**	**-**	**02**	**-**	**02**

$ indicates work load of Learner (Not Faculty)

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract./ Oral	Oral	
Test-I	Test-II	Average						
-	**-**	**-**	**-**	**-**	**25**	**-**	**25**	**50**

Course Objectives	**The course is aimed:** 1. To acquaint with the process of identifying the needs and converting it into the problem. 2. To familiarize the process of solving the problem in a group. 3. To acquaint with the process of applying basic engineering fundamentals to attempt solutions to the problems. 4. To inculcate the process of self-learning and research.
Course Outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Identify problems based on societal /research needs. 2. Apply Knowledge and skill to solve societal problems in a group. 3. Develop interpersonal skills to work as member of a group or leader. 4. Draw the proper inferences from available results through theoretical/ experimental/simulations. 5. Analyse the impact of solutions in societal and environmental context for sustainable development. 6. Use standard norms of engineering practices 7. Excel in written and oral communication. 8. Demonstrate capabilities of self-learning in a group, which leads to life long learning. 9. Demonstrate project management principles during project work.

General Guidelines for Mini Project 1A/ 1B

- Students shall form a group of 3 to 4 students, while forming a group shall not be allowed less than three or more than four students, as it is a group activity.
- Students should do survey and identify needs, which shall be converted into problem statement for mini project in consultation with faculty supervisor/head of department/internal committee of faculties.
- Students hall submit implementation plan in the form of Gantt/PERT/CPM chart, which will cover weekly activity of mini project.
- A log book to be prepared by each group, wherein group can record weekly work progress, guide/supervisor can verify and record notes/comments.
- Faculty supervisor may give inputs to students during mini project activity; however, focus shall be on self-learning.
- Students in a group shall understand problem effectively, propose multiple solution and select best possible solution in consultation with guide/ supervisor.
- Students shall convert the best solution into working model using various components of their domain areas and demonstrate.
- The solution to be validated with proper justification and report to be compiled in standard format of University of Mumbai.

- With the focus on the self-learning, innovation, addressing societal problems and entrepreneurship quality development within the students through the Mini Projects, it is preferable that a single project of appropriate level and quality to be carried out in two semesters by all the groups of the students. i.e. Mini Project-1 in semester III and IV. Similarly, Mini Project 2 in semesters V and VI.
- However, based on the individual students or group capability, with the mentor's recommendations, if the proposed Mini Project adhering to the qualitative aspects mentioned above gets completed in odd semester, then that group can be allowed to work on the extension of the Mini Project with suitable improvements/modifications or a completely new project idea in even semester. This policy can be adopted on case by case basis.

Mini Project 1A/1B–General Guidelines for Execution

Design and Fabrication

a. Initial fabrication of the project by students can be done using standard devices/material/software tools to verify the circuit functionalities Initial project fabrication and testing is expected to be done by soldering/assembling on general purpose PCB/ Bakelite boards or suitable platforms required for the electrical/electronic/digital components. Avoid the use of breadboards.
b. If essential, use of a simulation/ emulation software tools to test and verify the performance of the circuit should be encouraged.
c. Students should prepare the proper drawings (electrical/ mechanical), schematics/ layouts of the project.
d. For final implementation of the circuit, preparation of PCB (if any required) using suitable CAD tools and fabricating the same in the lab is expected.

Devices/ Components/ Systems to be Used:

Students are encouraged to use passive components like resistors, capacitors, inductors etc. If any specialize inductor is not readily available, the fabrication of the same in the lab should be encouraged. Other components like: Transistors, diodes, voltage regulators, logic gates, Op-amps, general purpose microcontroller, DC motors/ AC motors, sensors, actuators, relays etc. (Students may add more components as per the requirement of project).

Testing and analysis of the Project

Students should test the circuit using suitable laboratory equipments like power supply, multi-meter, CRO, DSO etc. In case of any debugging requirement, students should record the problems faced during the testing and solutions sought after for the fault in the circuit.

All the testing results must be well documented in the final project report verifying the functionalities of the propose project.

Use of Reference Material/Literature :

Students are advised to refer Application Notes, research publications & data sheets of various electrical/electronic/digital devices from Texas Instruments, Microchips, International Rectifiers, ST Microelectronics, Philips, NXP and many other manufacturers.

Self-learning and Skill Set Development

Students should be encouraged to develop/ improve their understanding and skill sets by attending various online/offline expert lectures / video lectures/ courses/ webinars/ workshops etc. to facilitate the smooth execution of mini project

1. Understanding passive components viz. resistors, capacitors and inductors from practical point of view: types/ varieties, device packages, applications and cost.
2. Understanding semiconductor components viz. diodes, BJT and JFET/MOSFETs from practical point of view: types/ varieties, device packages, applications and cost.
3. Design principles of simple electrical / electronic circuits with some examples.
4. Selection of switches and circuit protection components.
5. Selection and sizing of wires and conductors.
6. Soldering Practice.

7. Heat-sinking and Enclosure design concepts
8. Overall workmanship while working on the project fabrication.
9. Use of different software tools for design and development of circuits
10. Use of standard as well as advanced laboratory equipments needed for testing of such projects

Suggested Application Domains for Mini Projects:

List of key application domains from where students are encouraged to derive Mini Projects topics:

1. Home/Office automation
2. Renewable Energy
3. Energy Conservation
4. Energy Storage
5. Battery Charging and Protection
6. Fire Safety
7. Electrical System Protection
8. Lighting Control
9. Wireless Power Transfer
10. Electrical Components Testing
11. Electrical Parameters Measurement
12. Non-conventional Electricity Generation
13. Laboratory Equipments
14. E-Mobility
15. Video Surveillance Systems
16. Robotics for Hazardous applications
17. Waste Management System 2.
18. Smart City Solutions
19. Smart Classrooms and learning Solutions
20. Smart Agriculture solutions etc.
21. Health/ Biomedical

Students can identify the mini project topics either from above suggested domains or **any other relevant engineering domains**.

Guidelines for Assessment of Mini Project:

Term Work

- The review/ progress monitoring committee shall be constituted by head of departments of each institute. The progress of mini project to be evaluated on continuous basis, minimum two reviews in each semester.
- In continuous assessment focus shall also be on each individual student, assessment based on individual's contribution in group activity, their understanding and response to questions.
- Distribution of Term work marks for both semesters shall be as below;
  - Marks awarded by guide/supervisor based on log book : 10
  - Marks awarded by review committee : 10
  - Quality of Project report : 05

Review/progress monitoring committee may consider following points for assessment based on either one year or half year project as mentioned in general guidelines.

One-year Mini Project:

- In first semester entire theoretical solution shall be ready, including components/system selection and cost analysis. Two reviews will be conducted based on presentation given by students group.
  - First shall be for finalization of problem

    - Second shall be on finalization of proposed solution of problem.
- In second semester expected work shall be procurement of components /systems, building of working prototype, testing and validation of results based on work completed in an earlier semester.
    - First review is based on readiness of building working prototype to be conducted.
    - Second review shall be based on poster presentation cum demonstration of working model in last month of the said semester.

Half-year Mini Project:

- In this case in one semester students' group shall complete project in all aspects including,
    - Identification of need/problem
    - Proposed final solution
    - Procurement of components/systems
    - Building prototype and testing
- Two reviews will be conducted for continuous assessment,
    - First shall be for finalization of problem and proposed solution
    - Second shall be for implementation and testing of solution.

Assessment criteria of Mini Project.

Mini Project shall be assessed based on following criteria;

1. Quality of survey/ need identification
2. Clarity of Problem definition based on need.
3. Innovativeness in solutions
4. Feasibility of proposed problem solutions and selection of best solution
5. Cost effectiveness
6. Societal impact
7. Innovativeness
8. Cost effectiveness and Societal impact
9. Full functioning of working model as per stated requirements
10. Effective use of skill sets
11. Effective use of standard engineering norms
12. Contribution of an individual's as member or leader
13. Clarity in written and oral communication

- In **one year, project**, first semester evaluation may be based on first six criteria's and remaining may be used for second semester evaluation of performance of students in mini project.
- In case of **half year project** all criteria's in generic may be considered for evaluation of performance of students in mini project.

Guidelines for Assessment of Mini Project Practical/Oral Examination:

- Report should be prepared as per the guidelines issued by the University of Mumbai.
- Mini Project shall be assessed through a presentation and demonstration of working model by the student project group to a panel of Internal and External Examiners preferably from industry or research organizations having experience of more than five years approved by head of Institution.
- Students shall be motivated to publish a paper based on the work in Conferences/students competitions.

Oral Examination:

Mini Project shall be assessed based on following points;

1. Quality of problem and Clarity
2. Innovativeness in solutions
3. Cost effectiveness and Societal impact

4. Full functioning of working model as per stated requirements
5. Effective use of skill sets
6. Effective use of standard engineering norms
7. Contribution of an individual's as member or leader
8. Clarity in written and oral communication

Reference Books:

1. P. Horowitz and W. Hill, "The Art of Electronics", 3rd Edition, Cambridge University Press, 2015
2. R. S. Khandpur, "Printed Circuit Board", McGraw-Hill Education; 1st edition, 2005.
3. Simon Monk, "Hacking Electronic: Learning Arduino and Raspberry Pi", McGraw-Hill Education TAB; 2 edition (September 28, 2017).

Suggested Software Tools:

1. LTspice:https://www.analog.com/en/design-center/design-tools-and-calculators/ltspice-simulator.html#
2. Eagle : https://www.autodesk.in/products/eagle/overview
3. OrCAD: https://www.orcad.com/
4. Multisim : https://www.multisim.com/
5. Webbench:http://www.ti.com/design-resources/design-tools-simulation/webench-power-designer.html
6. Tinkercad : https://www.tinkercad.com/
7. Raspbian OS: https://www.raspberrypi.org/downloads
8. Arduino IDE: https://www.arduino.cc/en/main/software

Online Repository:

1. https://www.electronicsforu.com
2. https://circuitdigest.com
3. https://www.electronicshub.org
4. Github

Semester-IV								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEC401	**Engineering Mathematics-IV**	**03**	**-**	**01**	**03**	**-**	**01**	**04**

Examination Scheme								
Theory					Term Work/Practical/Oral			Total
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract.	Oral	
Test-I	Test-II	Average						
20	**20**	**20**	**80**	**03 Hrs**	**25**	**-**	**-**	**125**

Pre-requisite: Engineering Mathematics-I, Engineering Mathematics-II, Engineering Mathematics-III, Binomial Distribution.

Course Objectives	**The course is aimed:** 1. To study the line and contour integrals and expansion of complex valued function in a power series. 2. To understand the basic techniques of statistics for data analysis, Machine learning and AI. 3. To study the probability distributions and expectations. 4. To acquaint with the concepts of vector spaces used in the field of machine learning and engineering problems. 5. To familiarize with the concepts of Quadratic forms and Singular value decomposition. 6. To learn the concepts of Calculus of Variations.
Course Outcomes	**On successful completion of course learner/student will be able to:** 1. Use the concepts of Complex Integration for evaluating integrals, computing residues & evaluate various contour integrals. 2. Demonstrate the use of Correlation and Regression to the engineering problems in data science, machine learning and AI. 3. Illustrate understanding of the concepts of probability and expectation for getting the spread of the data and distribution of probabilities. 4. Apply the concept of vector spaces and orthogonalization process in Engineering Problems. 5. Use the concept of Quadratic forms and Singular value decomposition in various Engineering applications. 6. Find the extremals of the functional using the concept of Calculus of variation.

Module	Detailed Contents	Hours.
1	**Module: Complex Integration:** 1.1 Line Integral, Cauchy's Integral theorem for simple connected and multiply connected regions (without proof), Cauchy's Integral formula (without proof). 1.2 Taylor's and Laurent's series (without proof). 1.3 Definition of Singularity, Zeroes, poles of *f(z)*, Residues, Cauchy's Residue Theorem (without proof). **Self-learning Topics:** Application of Residue Theorem to evaluate real integrations, Z-Transform.	**07**

2	**Module: Statistical Techniques:** 2.1 Karl Pearson's Coefficient of correlation (r) 2.2 Spearman's Rank correlation coefficient (R) (repeated and non-repeated ranks) 2.3 Lines of regression. 2.4 Fitting of first and second degree curves. **Self-learning Topics:** Covariance, fitting of exponential curve.	**06**
3	**Module: Probability Distributions:** 2.1 Baye's Theorem, Random variable: Probability distribution for discrete and continuous random variables, Density function and distribution function. 3.2 Expectation, mean and variance. 3.3 Probability distribution: Poisson & normal distribution. **Self-learning Topics:** Moments, Moment Generating Function, Applications of Probability Distributions in Engineering.	**07**
4	**Module: Linear Algebra: Vector Spaces:** 4.1 Vectors in n-dimensional vector space, norm, dot product, The Cauchy-Schwarz inequality (with proof), Unit vector. 4.2 Orthogonal projection, Orthonormal basis, Gram-Schmidt process for vectors. 4.3 Vector spaces over real field, subspaces. **Self-Learning Topics**: Linear combinations, linear Dependence and Independence, QR decomposition.	**06**
5	**Module: Linear Algebra: Quadratic Forms:** 5.1 Quadratic forms over real field, Linear Transformation of Quadratic form, Reduction of Quadratic form to diagonal form using congruent transformation. 5.2 Rank, Index and Signature of quadratic form, Sylvester's law of inertia, Value- class of a quadratic form-Definite, Semidefinite and Indefinite. 5.3 Reduction of Quadratic form to a canonical form using congruent transformations. 5.4 Singular Value Decomposition. **Self-learning Topics:** Orthogonal Transformations**,** Applications of Quadratic forms and SVD in Engineering.	**07**
6	**Module: Calculus of Variations:** 6.1 Euler-Lagrange equation (Without Proof), When F does not contain y, When F does not contain x, When F contains x, y, y'. 6.2 Isoperimetric problems- Lagrange Method. 6.3 Functions involving higher order derivatives: Rayleigh-Ritz Method. **Self-Learning Topics:-** Brachistochrone Problem, Variational Problem, Hamilton Principle, Principle of Least action, Several dependent variables.	**06**

Term Work:

General Instructions:

1. Students must be encouraged to write at least 6 class tutorials on entire syllabus.
2. A group of 4-6 students should be assigned a self-learning topic. Students should prepare a presentation/problem solving of 10-15 minutes. This should be considered as mini project in Engineering Mathematics. This project should be graded for 10 marks depending on the performance of the students.

The distribution of Term Work marks will be as follows –

1.	Attendance (Theory and Tutorial)	05 marks
2.	Class Tutorials on entire syllabus	10 marks
3.	Mini project	10 marks

Assessment:

Internal Assessment Test:
Assessment consists of two class tests of 20 marks each. The first-class test (Internal Assessment I) is to be conducted when approx. 40% syllabus is completed and second class test (Internal Assessment II) when additional 40% (approx.)syllabus is completed. Duration of each test shall be one hour.

End Semester Theory Examination:
1. Question paper will comprise of total 06 questions, each carrying 20 marks.
2. Total 04 questions need to be solved.
3. Question No: 01 will be compulsory and based on entire syllabus wherein 4 sub-questions of 5 marks each will be asked.
4. Remaining questions will be randomly selected from all the modules.
5. Weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

Books Recommended:

Text Books:

1. Complex Variables and Applications, Brown and Churchill, McGraw-Hill education.
2. Probability, Statistics and Random Processes, T. Veerarajan, McGraw-Hill education.
3. Advanced engineering mathematics, H.K. Das, S. Chand, Publications.
4. Higher Engineering Mathematics, B. V. Ramana, Tata Mc-Graw Hill Publication
5. Advanced Engineering Mathematics, R. K. Jain and S. R. K. Iyengar, Narosa publication
6. Advanced Engineering Mathematics, Wylie and Barret, Tata Mc-Graw Hill.
7. Beginning Linear Algebra, Seymour Lipschutz Schaum's outline series, McGraw Hill Publication
8. Higher Engineering Mathematics, Dr. B. S. Grewal, Khanna Publication

Semester-IV								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEC402	**Electrical AC Machines - I**	**03**	**-**	**-**	**03**	**-**	**-**	**03**

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract.	Oral	
Test-I	Test-II	Average						
20	**20**	**20**	**80**	**03 Hrs**	**-**	**-**	**-**	**100**

Course Objectives	**The course is aimed:** 1. To impart knowledge of performance and operation of an induction motor. 2. To impart the knowledge of working principle, operations, performance and applications of single phase and three phase Transformers.
Course Outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Illustrate working principle and performance of single phase transformer under different operating conditions 2. Understand working principle of autotransformer. 3. Analyze various types of connections and performance of three phase transformer under various conditions. 4. Demonstrate working principle and evaluate the performance of three phase induction motor under various operating conditions. 5. Exemplify various starting methods and speed control of three phase induction motor.

Module	Detailed Contents	Hours
1	**Single phase Transformer:** Review of working principle, EMF equation and Equivalent Circuit, Phasor diagram (Resistive, Inductive and capacitive load), voltage regulation, Losses and Efficiency, Condition for Maximum Efficiency, Parallel Operation: No load Operation, On load Operation: - Equal Voltage Operation and Unequal Voltage Operation, Testing of Transformer: OC and SC test, Sumpner's Test	**07**
2	**Autotransformer:** Working, Advantages of Autotransformer over two winding Transformer, Disadvantages, Isolation Transformer working and its applications.	**02**
3	**Three Phase Transformer:** Constructional details, Principle of operation, Connections and Phasor groups, Parallel operation, Excitation Phenomenon in transformers, Harmonics in three phase transformers, Suppression of harmonics, Oscillating neutral phenomenon, Switching intransient phenomenon, Open delta or V - connection, Three phases to two phase conversion (Scott connection).	**08**
4	**Three Phase Induction Motor:** Review of Constructional details and Principle of operation, Slip, Rotor emf and frequency, current and power, Power stages, Phasor diagram, Equivalent circuit, Torque-speed characteristics in braking ,motoring and generating regions, Losses and efficiency, No load and blocked rotor test, Circle diagram, Applications.	**10**

5	**Starting and Speed control of Three Phase Induction Motor:** Need of starter, Types of starters: Direct On Line (DOL) starter, Rotor resistance starter, Autotransformer and Star delta starters, Speed control: Voltage control, Frequency control, Pole changing method, V/f control.	**06**
6	**Single phase Induction Motor**: Principle of operation (Review), Double field revolving theory, Equivalent circuit of single phase induction motor, Determination of equivalent circuit parameters from no load and block rotor test, Staring methods, Split phase starting- Resistance spilt phase, capacitor split phase, capacitor start and run, shaded pole starting, Applications of 1ϕ IM	**06**

Assessment:

Internal Assessment Test:

Assessment consists of two class tests of 20 marks each. The first-class test (Internal Assessment I) is to be conducted when approx. 40% syllabus is completed and second class test (Internal Assessment II) when additional 40% (approx..) syllabus is completed. Duration of each test shall be one hour.

End Semester Theory Examination:

1. Question paper will comprise of total 06 questions, each carrying 20 marks.
2. Total 04 questions need to be solved.
3. Question No: 01 will be compulsory and based on entire syllabus wherein 4 sub-questions of 5 marks each will be asked.
4. Remaining questions will be randomly selected from all the modules.
5. Weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

Books Recommended:

Text Books:

1. Bimbhra P.S., *Electric Machinery* , Khanna Publisher
2. Bimbhra P.S., *Generalized Machine Theory*, Khanna Publisher
3. V. K. Mehta, *Principles of Electrical Machines*, S Chand Publication

Reference Books:

1. M.G. Say, Performance and Design of Alternating Current Machines, CBS Pub.
2. Ashfaq Husain, *Electric Machines***,** Dhanpat Rai and Co.
3. A.E. Fitzgerald, Kingsly, Stephen., *Electric Machinery*, Tata McGraw Hill

NPTEL/ Swayam Course:

1. **Course: Electrical Machines – II By Prof. Tapas Kumar Bhattacharya (IIT Kharagpur)**
   https://nptel.ac.in/noc/courses/noc19/SEM1/noc19-ee01/
2. **Course: Electrical Machines By Prof. Bhuvaneshwari (IIT Delhi)**
   https://swayam.gov.in/nd1_noc19_ee69/preview

Semester-IV								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEC403	**Digital Electronics**	**03**	**-**	**-**	**03**	**-**	**-**	**03**

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract.	Oral	
Test-I	Test-II	Average						
20	**20**	**20**	**80**	**03 Hrs**	**-**	**-**	**-**	**100**

Course Objectives	**The course is aimed:** 1. To understand working of logic families and logic gates. 2. To study the combinational and sequential logic circuits. 3. To understand Analog to Digital and Digital to Analog conversions. 4. To introduce ROM as Programmable Logic Device.
Course Outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Perform conversion of various number systems 2. Understand working of logic families and logic gates. 3. Design and implement combinational circuits. 4. Design and implement sequential circuits. 5. Understand the process of Analog to Digital conversion and Digital to Analog conversion. 6. Illustrate the use of PLDs to implement the given logical problem.

Module	Detailed Contents	Hours
1	**Fundamentals of Digital Systems and Logic families:** Number formats: Binary, signed binary, Octal, hexadecimal, BCD and their basic math operations (addition and subtraction) Logic gates: Digital signals, digital circuits, AND, OR, NOT, NAND, NOR and Exclusive-OR operations, Boolean Algebra, Specifications of Digital IC Logic Families: TTL, CMOS logic families, Comparison of TTL and CMOS, Interfacing of TTL and CMOS, Tri-state logic	**07**
2	**Combinational Digital Circuits:** Design & Simplification of logic functions: K-map representation, simplification of logic functions using K-map (upto 4 variables), Minterm, maxterm, SOP and POS implementation, realization of logic function using universal gates Binary Arithmetic circuits: Adder and Subtractor (Half and Full), Multiplier, 2 bit comparators, Multiplexer, de-multiplexer, decoder Designing code converter circuit: binary to gray, Gray to Binary, Multiplexer (ULM), De-multiplexers, BCD to 7 segment	**10**
3	**Sequential Digital Circuits** Comparison of combinational & sequential circuit, Flip-flops -SR, JK,T, D, Master Slave JK, Counters-Modulus of counter, Design of Synchronous, Asynchronous counters, Ripple Up/Down Counter, Ring counter, Shift Registers –Right and left shift registers, Serial to parallel converter, parallel to serial converter, applications of counters.	**06**
4	**A/D and D/A Converters:** Digital to Analog converter: Weighted resistor converter, R-2R ladder D/A converter, examples of D/A converter ICs.	**05**

	Analog to Digital converter: sample and hold circuit, Quantization and encoding, successive approximation A/D converter, dual slope A/D converter, voltage to frequency and voltage to time conversion, specifications of A/D converters, example of A/D converter ICs	
5	**Semiconductor Memories:** Classification and characteristics of memories, Memory organization and operation, expanding memory size- Memory mapping and address decoding , sequential memory, read only memory (ROM), read and write memory (RAM), content addressable memory (CAM), commonly used memory chips	**06**
6	**Programmable Logic Devices:** ROM as a programmable logic device, programmable logic array, programmable array logic, Complex Programmable Logic Devices (CPLDs), Field Programmable Gate Array (FPGA)	**05**

Assessment:

Internal Assessment Test:

Assessment consists of two class tests of 20 marks each. The first-class test (Internal Assessment I) is to be conducted when approx. 40% syllabus is completed and second class test (Internal Assessment II) when additional 40% (approx.) syllabus is completed. Duration of each test shall be one hour.

End Semester Theory Examination:

1. Question paper will comprise of total 06 questions, each carrying 20 marks.
2. Total 04 questions need to be solved.
3. Question No: 01 will be compulsory and based on entire syllabus wherein 4 sub-questions of 5 marks each will be asked.
4. Remaining questions will be randomly selected from all the modules.
5. Weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

Books Recommended:

Text Books:

1. Anand Kumar, “Fundamentals of Digital Circuits”, Prentice Hall India, 2016
2. R. P. Jain, “Modern Digital Electronics” Tata McGraw Hill Education, 2009
3. Morris. M. Mano, “Digital Logic and Computer design”, Pearson Education India, 2016
4. Alan b. Marcovitz, “Introduction to logic Design”, McGraw Hill International 2002.
5. Malvino & Leach, Digital principal and Application”, Tata McGraw Hill, 1991

NPTEL/ Swayam Course:

1. **Course: Digital Electronic Circuits By Prof. Goutam Saha (IIT Kharagpur)**
   https://swayam.gov.in/nd1_noc20_ee32/preview
2. **Course: Digital Circuits and Systems - Video course By Prof. S. Srinivasan (IIT Madras)**
   https://nptel.ac.in/courses/117/106/117106086/

Semester-IV								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEC404	**Power Electronic Devices and Circuits**	**03**	**-**	**-**	**03**	**-**	**-**	**03**

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract.	Oral	
Test-I	Test-II	Average						
20	**20**	**20**	**80**	**03 Hrs**	**-**	**-**	**-**	**100**

Course Objectives	**The course is aimed:** 1. To impart knowledge about various power semiconductor devices related to its characteristics, ratings, protection and facilitate selection of semiconductor devices for various applications. 2. To introduce different power conversion topologies such as ac to dc, dc to dc, dc to ac and the underlying principles of converter operation aiding to analyse their performance. 3. To keep abreast with the latest technologies and research going on in different domains related to power electronics.
Course Outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Understand the basic operation and characteristics of various semi controllable and fully controllable devices 2. Analyse various single phase and three phase power converter circuits and understand their applications. 3. Analyse dc to dc converter circuits and their applications. 4. Identify and describe various auxiliary circuits and requirements in power electronics applications such as gate driver circuit, snubber circuits and heat sinks. 5. Apply the basic concepts to select devices and converters for various applications

Module	Detailed Content	Hours
1	**Thyristors:** Basic operation of silicon controlled rectifier, Static characteristics, two transistor analogy, Dynamic characteristics, Firing circuits (R,RC, Ramp triggering using UJT), Commutation circuits, Protection circuit of SCR. **Self study topic**: Other devices of Thyristor family	**07**
2	**Power semiconductor devices:** Basic operation and characteristics of power diodes, power BJTs, power MOSFETs, IGBTs, Safe Operation Area (SOA) for each devices, Silicon Carbide (SiC) and GaN devices, Comparison of devices, selection of devices for various applications, Conduction and switching losses.	**06**
3	**Controlled Rectifiers:** Single phase half wave rectifiers, full wave rectifiers (mid-point and bridge configuration) for R and R-L load, freewheel diode, Rectification and inversion mode of single phase fully controlled rectifier, single phase dual converter, Three phase semi converter and full converter with R load, Applications, calculation of output voltage, single phase PWM rectifier, basic working principle and applications.	**08**
4	**Inverter:** Classification based on source and power level, Single phase bridge Inverters (VSI), Performance parameters, Three phase VSI (120° and 180° conduction mode), Voltage	**06**

	control of single phase inverters- PWM techniques-Single PWM, Multiple PWM, Sinusoidal PWM, Basics of Space vector modulation, Single phase current source inverters (CSI), comparison of VSI and CSI.	
5	**DC to DC Converter**: Introduction, Switching mode regulators – Buck, Boost, Buck-Boost, bidirectional dc to dc converters, all with resistive load and only CCM mode, Applications: Power Factor Correction Circuits, LED lamp driver.	**07**
6	**Auxiliary Circuits**: Types of drivers-level shifters, bootstrap drivers, isolated drivers, Gate Drive circuitry for Power Converters, methods of current and voltage measurement, snubber circuits and heat sinks.	**05**

Assessment:

Internal Assessment Test:

Assessment consists of two class tests of 20 marks each. The first-class test (Internal Assessment I) is to be conducted when approx. 40% syllabus is completed and second class test (Internal Assessment II) when additional 40% (approx.) syllabus is completed. Duration of each test shall be one hour.

End Semester Theory Examination:

1. Question paper will comprise of total 06 questions, each carrying 20 marks.
2. Total 04 questions need to be solved.
3. Question No: 01 will be compulsory and based on entire syllabus wherein 4 sub-questions of 5 marks each will be asked.
4. Remaining questions will be randomly selected from all the modules.
5. Weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

Books Recommended:

Text Books:

1. M. H. Rashid, *Power Electronics: Circuits, Devices, and Applications*, Pearson Education, 2009.
2. N. Mohan and T. M. Undeland, *Power Electronics: Converters, Applications and Design*, John Wiley & Sons, 2007.
3. R.W. Erickson and D. Maksimovic, *Fundamentals of Power Electronics*, Springer Science & Business Media, 2007.
4. L. Umanand, *Power Electronics: Essentials and Applications*, Wiley India, 2009.
5. P.C Sen., *Modern Power Electronics*, Wheeler publishing Company, 1st Edition, 2005
6. Alok Jain, *Power Electronics: Devices, Circuits and Matlab Simulations*, Penram Int. 2010
7. B. Jayant Baliga, *Silicon Carbide Power Devices*, World Scientific, 2005.

Reference Books:

1. C.W. Landers, *Power Electronics*, McGraw Hill, 1993
2. Ashfaq Ahmed, *Power Electronics for Technology*, Pearson, 1998
3. Joseph Vithayathil, *Power Electronics*, Tata McGraw hill, 1995.
4. P. Friedrichs, T. Kimoto, L. Ley and G. Pensl, *Silicon Carbide, Volume 2: Power Devices and Sensors*, Wiley Publications, 2011.
5. Dokić, Branko L. and Blanuša, Branko, *Power Electronics Converters and Regulators* Springer International Publishing, 2015

NPTEL/ Swayam Course:

1. **Course: Advance Power Electronics And Control – Prof. Avik Bhattacharya (IIT Roorkee) https://nptel.ac.in/courses/108/107/108107128/**
2. **Course: Power Electronics By Prof. G. Bhuvaneshwari (IIT Delhi) https://swayam.gov.in/nd1_noc20_ee97/preview**

Semester IV								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEC405	**Electric and Hybrid Electric Vehicle**	**03**	**-**	**-**	**03**	**-**	**-**	**03**

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract.	Oral	
Test-I	Test-II	Average						
20	**20**	**20**	**80**	**03 Hrs**	**-**	**-**	**-**	**100**

Course Objectives	**The course is aimed:** 1. To learn the history of electric hybrid electric vehicles (EV & HEV) and emphasize the need and importance of EV-HEV for sustainable future. 2. To study the fundamental concepts and principles of electric and hybrid electric vehicles drive train topologies 3. To develop a thorough understanding of the key elements of EV/HEV: Electric Machines for Propulsion Applications and Energy Sources 4. To model, analyze and design electric and hybrid electric vehicles drive train and to understand energy management strategies
Course outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Identify and describe the history and evolvement of electric & hybrid electric vehicles. 2. Identify and describe the principles of various EV/HEVs drive train topologies. 3. Select electric propulsion system components for EV/HEV drives for the desirable performance and control**.** 4. Compare and evaluate various energy sources and energy storage components for EV/HEV. 5. Model, analyze and design EV/HEV drive train with energy management strategies**.** 6. Recognize the need to adapt and engage in operations EV/HEV for sustainable transportation system.

Module	Detailed Contents	Hours
1	**Introduction:** Basics of vehicles mechanisms**,** history of electric vehicles (EV) and hybrid electric vehicles (HEV), need and importance of EV and HEV, Power/Energy supplies requirements for EV/HEV applications. State of the art and Indian and global scenario in EV/HEV	**04**
2	**Drive-train Topologies:** Various electric drive-train topologies, basics of hybrid traction system, various hybrid drive-train topologies, power flow control in drive-train topologies, fuel efficiency analysis.	**07**
3	**DC and AC Machines for Propulsion Applications:** Electric system components for EV/HEV, suitability of DC and AC machines for EV/HEV applications, AC and DC Motor drives.	**05**
4	**Energy Sources for EV/HEV:** Requirements of energy storage in EV/HEV: batteries, fuel cells, flywheels and ultra-capacitors as energy sources for EV/HEV, characteristics and comparison of	**10**

	energy sources for EV/HEV, hybridization of different energy sources. EV battery chargers: AC and DC, Fast chargers and related standards	
5	**Drive-train Modelling and Design Considerations :** Modeling and analysis of EV/HEV drive train: Total tractive force calculation, sizing of motor, and design considerations for power electronics drive.	**08**
6	**Energy Management Strategies and Energy Efficiency:** EV/HEV energy management strategies, classification and comparison of various energy management strategies. Basic EV AC and DC Chargers, G2V and V2G concept.	**05**

Self-study: Testing and Evaluation Standards for EV & HEV available on Automotive Research Association of India (ARAI) website: https://emobility.araiindia.com/standards/

Assessment:

Internal Assessment Test:

Assessment consists of two class tests of 20 marks each. The first-class test (Internal Assessment I) is to be conducted when approx. 40% syllabus is completed and second class test (Internal Assessment II) when additional 40% (approx.) syllabus is completed. Duration of each test shall be one hour.

End Semester Theory Examination:

1. Question paper will comprise of total 06 questions, each carrying 20 marks.
2. Total 04 questions need to be solved.
3. Question No: 01 will be compulsory and based on entire syllabus wherein 4 sub-questions of 5 marks each will be asked.
4. Remaining questions will be randomly selected from all the modules.
5. Weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

Books Recommended:

Text Books:

1. I. Hussein, *Electric and Hybrid Vehicles: Design Fundamentals*, CRC Press, 2003.
2. M. Ehsani, Y. Gao, S.E. Gay and Ali Emadi, *Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design*, CRC Press. 2005
3. Sheldon Williamsom, *Energy Management Strategies for Electric and Plug-in Hybrid Vehicles*, Springer 2013
4. J. Larminie and J. Lowry, *Electric Vehicle Technology Explained*, Wiley, 2003
5. C. MI, M. Abul and D. W. Gao, *Hybrid Electrical Vehicle Principles and Application with Practical Perspectives,* Wiley 2011

Reference Books:

1. N.Mohan, T.M.Undeland, and W.P Robbins, *Power Electronics, Converters, Applications & Design,* Wiley India Pvt. Ltd., 2003
2. B. K Bose*, Modern Power Electronics and AC Drives*, Pearson Education 2002
3. Robert A. Huggins, *Energy Storage*, Springer 2010

NPTEL/ Swayam Course:

1. **Course: Intro. to Hybrid and Electric Vehicles - Prof. Praveen Kumar & Prof. S. Majhi (IIT Guwahati): https://nptel.ac.in/courses/108/103/108103009/**
2. **Course: Electric Vehicles - Part 1 By Prof. Amit Kumar Jain (IIT Delhi) https://nptel.ac.in/courses/108/102/108102121/**

Semester-IV								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEL401	**Electrical AC Machines Lab-I**	-	**02**	**-**	**-**	**01**	**-**	**01**

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract./ Oral	Oral	
Test-I	Test-II	Average						
-	**-**	**-**	**-**	**-**	**25**	**25**	**-**	**50**

Course Objectives	**To impart the knowledge on :** 1. Construction, principle of operation, design, performance and applications of single and three phase Transformers 2. Construction, principle of operation, design, performance and applications of single and three phase Induction Motors.
Course Outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Demonstrate the working principles and types of connections of 1φ and 3φ transformers. 2. Analyze the performance of 3φ transformer under various operating conditions. 3. Evaluate the performance of 3φ induction motor by carrying no load test , blocked rotor test and load test 4. Illustrate the operation of various type of 3φ induction motor starters. 5. Illustrate different methods of speed control and braking of 3φ induction motors.

Syllabus: Same as **EEC402- Electrical AC Machines-I**

Suggested List of Laboratory Experiments: Minimum eight experiments need to be performed.

1. Study of transformer connections**.**
2. Sumpner's test on single phase transformer
3. Open circuit & short circuit test on three phase transformer.
4. Parallel operation of transformers.
5. Scott connection of transformer.
6. Open Delta (V) connection of transformer
7. Load Test on three phase squirrel cage induction motor.
8. Load test on three phase slip ring induction motor.
9. No load and Blocked rotor test on three phase induction motor. (Determination of equivalent circuit parameters)
10. Separation of no load losses of three phase induction motor.
11. Performance analysis of three phase induction motor using circle diagram.
12. Study of different types of induction motor starters.
13. Speed control by v/f method.
14. Study of induction motor braking methods
15. Open circuit and short circuit test on single phase transformer and find equivalent circuit parameters.
16. No load and block rotor test on single phase induction motor.
17. Load test on single phase induction motor.

Any other experiments based on syllabus which will help students to understand topic/concept.

Note:

Students and teachers are encouraged to use the 'Virtual Labs' (an MHRD Govt. of India Initiative) whose links are as given below. The remote-access to Labs in various disciplines of Science and Engineering is available. Students can conduct experiments which would help them in learning basic and advanced concepts through remote experimentation.

Virtual Lab Website Reference

1. http://vlab.co.in/broad-area-electrical-engineering
2. http://vlab.co.in/broad-area-electronics-and-communications

Term work:

Term work shall consist of minimum 8 experiments. The distribution of marks for term work shall be as follows:

Laboratory performance	: 10 marks
Journal	: 10 marks
Attendance	: 05 marks

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

Practical / Oral Examination:

Practical exam will be based on all the laboratory experiments carried out and Oral examination will be based on entire syllabus of **EEC402-Electrical AC Machines-I**
The distribution of marks for practical examination shall be as follows:

- Practical Exam : 15 marks
- Oral Exam : 10 marks

Semester-IV								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEL402	**Python Programming Lab**	-	**02**	**-**	**-**	**01**	**-**	**01**

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract./ Oral	Oral	
Test-I	Test-II	Average						
-	**-**	**-**	**-**	**-**	**25**	**25**	**--**	**50**

Course Objectives	**The course is aimed:** 1. To introduce core programming basics and program design with functions using Python programming language. 2. To study the use of procedural statements like assignments, conditional statements, loops and function calls. 3. To learn the supported data structures like lists, dictionaries and tuples in Python. 4. To describe the need for Object-oriented programming concepts in Python.
Course Outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Describe the numbers, Math functions, Strings, List, Tuples and Dictionaries in Python 2. Express different Decision Making statements and Functions 3. Illustrate the skill of object oriented programming in Python to develop applications in electrical engineering 4. Understand different File handling operations 5. Understand the design of GUI Applications in Python and evaluate different database operations

Prerequisite: Basic Programming syntax of Java/C.

Module	Detailed Contents	Hours
1	**Basics of Python** **Theory:** Numbers in Python, Basic & Built-in Math functions, Number Formats, Strings, Quotes, print () Function, Assigning Values to Names & Changing Data Through Names, Copying Data, Tuples-Unchanging Sequences of Data, Lists-Changeable Sequences of Data; Dictionaries - Groupings of Data Indexed by Name, Special String Substitution Using Dictionaries, Arrays, Treating a String Like a List, Special Types, Ranges of Sequences, Working with Sets, Arrays. **Lab Experiment:** Write python programs to understand Expressions, Variables, Quotes, Basic Math operations, Strings: Basic String Operations & String Methods, List, Tuples, Dictionaries, Arrays (**Minimum Two Programs** based on math operations, Strings and List/Tuples/ Dictionaries)	**05**
2	**Decision Making and Functions:** **Theory:** If statement, if-elif-else, Repetition using while loop, for loop, break statement, Handling Errors- try: statement, except: statement, Functions-Grouping Code under a Name, defining a Function, function in the function, Checking & Setting Your Parameters, Calling Functions from within Other Functions, Functions Inside of Functions, Layers of Functions	**05**

	Lab Experiment: Write python programs to understand different decision making statements and Functions. (**Minimum Two Programs** based on Decision making, Looping Statements and Functions)	
3	**Object Oriented Programming using Python programming:** **Theory**: Creating a Class, Self Variables, Constructors, Types of Methods, Inner Classes, Constructors in Inheritance, Polymorphism, Interfaces in Python. Exceptions Handling: Errors in a Python Program, Exceptions, Exception Handling, Types of Exceptions. **Lab Experiment:** Write python programs to understand different Object oriented features in Python (**Minimum Two programs** based on a) Classes & objects, b) Constructors, c) Inheritance & Polymorphism, d) Exception handling.	**05**
4	**Advanced Python Libraries:** **Introduction to Objects and Functions** of a. Numpy - core library for scientific computing b. Pandas - fast, powerful, flexible and easy to use open source data analysis and manipulation tool c. MatplotLib - comprehensive library for creating static, animated, and interactive visualizations d. SciPy - ecosystem of open-source software for mathematics, science, and engineering **Lab Experiment:** Write **Minimum Two programs** python programs to understand different functionalities exposed by each of the above libraries.	**07**
5	**GUI Programming and Databases Theory**: **GUI Programming** - Writing a GUI with Python: GUI Programming Toolkits, Creating GUI Widgets with Tkinter, Creating Layouts, Radio Buttons and Checkboxes, Dialog Boxes. Database Access - Python's Database Connectivity, Types of Databases Used with Python, Mysql database Connectivity with Python, Performing Insert, Deleting & Update operations on database **Lab Experiment:** Students should be given demonstration of GUI designing and database operations.	**04**

Term work:

Term work shall consist of minimum 08 experiments. The distribution of marks for term work shall be as follows:

Laboratory Performance : 20 marks
Attendance : 05 marks

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

Practical/ Oral Examination:

Practical / Oral examination will be based on all the lab experiments carried out and the entire syllabus of EEL402- Python Programming Lab. The distribution of marks for practical examination shall be as follows: Practical Exam- 15 marks and Oral Exam -10 marks.

Reference Books:

1. Mark Lutz, *Learning Python*, O Reily, 4thEdition, 2009,
2. Mark Lutz, *Programming Python*, O Reily, 4thEdition, 2010
3. Tim Hall and J-P Stacey, *Python 3 for Absolute Beginners*, 2009.
4. Magnus Lie Hetland, *Beginning Python: From Novice to Professional*, 2nd Edition, 2009.
5. Wesley J. Chun, *Core Python Programming*, Second Edition, Pearson
6. Jeeva Jose, *Taming Python by Programming*, Khanna Publishing House
7. J. Jose, *Introduction to Computing and Problem Solving with Python*, Khanna Publications
8. Seema Thareja, *Python Programming*, Pearson

Semester-IV								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEL403	**Electronics Lab II**	-	**02**	**-**	**-**	**01**	**-**	**01**

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract./ Oral	Oral	
Test-I	Test-II	Average						
-	**-**	**-**	**-**	**-**	**25**	**25**	**-**	**25**

Course Objectives	**The course is aimed:** 1. To introduce the basic building blocks and applications Digital logic devices. 2. To illustrate the students to practical circuits based on the power electronics devices used in various applications.
Course Outcomes	**Upon successful completion of this course, the learner will be able to** 1. Use various digital logic Gates, flip-flops and counters for various applications 2. Build, design and analyse sequential / combinational circuits. 3. Understand the operation various power electronics devices and circuits 4. Use power converters for various real life applications 5. Realize the implementation of digital interface with power electronics converters

Syllabus: Same as that of Course **EEC403- Digital Electronics** and **EEC404-Power Electronics Devices and Circuits.**

Suggested List of Laboratory Experiments: Minimum four experiments from each Group A and Group B (total minimum eight) need to be performed.

Group A: EEC405- Digital Electronics

1. SOP and POS Minimization (different problem statement for each student)
2. Characteristics of TTL and MOS logic family
3. Implementation of counters with flip-flops.
4. Constructing flip-flops using all NAND gates.
5. Designing a mod N counter where N <14 using J K flip-flops and D flip-flops.
6. Design of a ripple counter
7. Design two bit comparator using gate ICs.
8. Study of Analog to Digital Converter
9. Study of Digital to Analog Converter
10. Any one of the following
    (i) Full Adder using Gates and using Decoder or a Multiplexer.
    (ii)Using a shift register as a sequence generator.

Group B: EEC403-Power Electronics Devices and Circuits:

1. Study of I-V characteristics of Thyristors (SCR/Triac)
2. Study of switching characteristics of Power BJT/ Power MOSFET/ IGBT
3. Implementation of Single phase Half wave and Full wave rectifiers
4. Study of single phase PWM rectifier
5. Implementation and testing of SPWM VSI.
6. Design of IGBT gate drivers circuit
7. Design and Implementation of DC-DC Buck converter

8. Design and Implementation of DC-DC Boost converter
9. Implementation and testing of LED driver circuit
10. Study of current and voltage measurement circuits in switching converters
11. Study of Analog to Digital Converter

Any other experiments based on syllabus which will help students to understand topic/concept.

Note:

Students and teachers are encouraged to use the 'Virtual Labs' (an MHRD Govt. of India Initiative) whose links are as given below. The remote-access to Labs in various disciplines of Science and Engineering is available. Students can conduct experiments which would help them in learning basic and advanced concepts through remote experimentation.

Virtual Lab Website Reference

1. http://vlab.co.in/broad-area-electrical-engineering
2. http://vlab.co.in/broad-area-electronics-and-communications

Term work:

Term work shall consist of minimum 08 experiments. The distribution of marks for term work shall be as follows:

Laboratory Performance	: 10 marks
Journal	: 10 marks
Attendance	: 05 marks

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

Practical and Oral Examination:

Practical will be based on all the laboratory experiments carried out and Oral examination will be based on entire syllabus of **EEC403 - Digital Electronics** and **EEC404 - Power Electronics Devices and Circuits**

The distribution of marks for practical examination shall be as follows:

- Practical Exam : 15 marks
- Oral Exam : 10 marks

Semester-IV								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEL404	**Skill Based Lab- II PCB Design and Fabrication Lab**	-	**04**	**-**	**-**	**02**	**-**	**02**

Examination Scheme								
Theory					Term Work/Practical/Oral			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract./ Oral	Oral	
Test-I	Test-II	Average						
-	-	-	-	-	**50**	-	-	**50**

Course Objectives	**The course is aimed:** 1. To develop the skill set to work on real-life projects and its design. 2. To develop the required skill set to design, develop and assemble the PCB using the CAD tools
Course Outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Understand types of PCBs and various tools used for PCB design. 2. Identify various electrical/electronic components and their packages/ footprints. 3. Illustrate the use of PCB CAD tools and their features for the practical designs. 4. Design the schematic, board layout for simple, moderately complex and complex circuits. 5. Fabricate and assemble the PCBs for simple and moderately complex circuits.

Module	Detailed Contents	Hours
1	**Basics of PCB Designing:** Types of PCBs, Single Layer, Multi-Layer, PCB Materials, PCB designing using different PCB-CAD tools; Schematic Editor, Component libraries with model and footprint, Circuit Emulation, Artwork with auto / manual routing and 3-D Visualization.	**06**
2	**Electrical/ Electronic Components and Packages:** Semiconductor devices and footprints: Diodes: rectifier/ ultrafast/ schottky/ power/ zener diodes, LED, transistors(BJT), SCRs, GTOs, MOSFETs, IGBTs, DIACs, TRIACs etc; Integrated circuits (ICs) and Opto-isolators Different PCB connectors, Terminals, Terminal Blocks; Inductor and Transformers: pulse, low and high frequency); Capacitors and resistors; High voltage devices, Protection elements Component package types: Through Hole Packages: Axial lead, Radial Lead, Single Inline Package(SIP), Dual Inline Package(DIP), Transistor Outline(TO), Through Hole Packages, surface mounted devices (SMD) components.	**06**
3	**PCB Development Tools:** Introduction to open source and commercial softwares like: Proteus, Altium, Eagle, OrCAD, KiCAD etc. Schematic preparation, Selection of Components from standard and special libraries, Components Footprints, net-list, creating new component footprints / library. Updating libraries	**06**

4	**PCB Artwork Designing:** PCB Layout Designing: Placement and layout of components, Design Rule Check (DRC), Electronic rule checking (ERC); PCB Layers: electrical Layers: top Layer, bottom Layer, board outlines and cut-outs, drilling details, components outlines, text; pads, vias, Tracks, colour of layers; Multilayer PCBs. PCB materials: Standard FR-4 Epoxy Glass, Multi-functional FR-4, Tetra Functional FR-4, Polyimide Glass, Teflon etc. Rules for track: PCB conducting layer thickness selection, PCB track width calculation, track length, track angle, track joints, track size; manual routing, auto-routing: Setting up Rules, Defining Constraints; Gerber Generation; PCB Fabrication PCB Making, Printing, Etching, Drilling. EMI and EMC issues in PCB designing.	**10**
5	**PCB Designing in Lab:** **Students should prepare PCBs for at least three projects:** • First project should be a simple circuit: Complete schematic, board layout (single-sided), PCB fabrication, component mounting and testing to be completed. • Second project should be a moderately complex circuit: Complete schematic, board layout (Single layer), PCB fabrication, component mounting and testing to be completed • Third project should be a complex circuit: Complete schematic and board layout (multi-layer) design, gerber files generation to be completed. All three projects are required to be carried out by each individual student (not in a group). For each project a detailed report inclusive of all the schematic, artwork layouts, PCB photos, assembled PCB photos, details of the circuit design and test result etc. must be prepared. Each Project can be carried out based on the following steps: **PCB project:** Selection of circuit, components, components packages, manufacturer (make), generic components, symbols. (i) Selection of circuit: PCB design practice can be carried out for following circuits: 1. Analog Electrical / Electronic Circuits 2. Linear DC Power Supply 3. Op-amp based Signal Processing circuits 4. Different measurement based on transducers /sensors. 5. Mini Project based on Electrical / Electronic domain 6. Microcontroller circuits etc. (ii) Components selection: Students can design/ select the components from datasheets/ manufacturer catalogues / data-book, online supplier's inventory etc. (iii) Selection of PCB type: PCB material, number of layers, thickness of copper etc. (iv) Prepare the schematic and board layout using the open source CAD tools or Licensed CAD tool available in the lab. (v) Fabricate PCB in the lab using printing, etching and drilling process.(Only two projects) (vi) Post PCB fabrication process: component mounting, soldering and Hardware Testing. (vii) Prepare the report on overall lab work carried out with schematics, PCB artwork final PCB fabrication and assembled PCBs photographs.	**24**

Term Work:

Term work shall consist of minimum three PCB designing projects and the reports based on that. The distribution of marks for term work shall be as follows:

Laboratory Performance : 30 marks (PCB design and fabrication- 10 each for three PCBs based on workmanship and quality of work)
Journal : 10 marks
Attendance : 10 marks

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

Books Recommended:

1. Simon Monk, *Make Your Own PCBs with EAGLE: From Schematic Designs to Finished Boards,* 1st Edition, McGraw-Hill Education
2. P. Horowitz and W. Hill*, The Art of Electronics,* 3 Edition, Cambridge University Press.
3. Matthew Scarpino, *Designing Circuit Boards with EAGLE: Make High-Quality PCBs at Low Cost*, 1st Edition Prentice Hall.
4. Archambeault and Drewniak James, *PCB Design for Real-World EMI Control, Springer Publications*

Note: Online demonstrative videos provided by various PCB CAD tools developers can be used to train the students to enable them to gain required skill sets in PCB designing and fabrication essential in engineering career.

Semester-IV								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEM401	**Mini Project – 1B**	-	**04$**	**-**	**-**	**02**	**-**	**02**

$ indicates work load of Learner (Not Faculty)

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract./ Oral	Oral	
Test-I	Test-II	Average						
-	**-**	**-**	**-**	**-**	**25**	**-**	**25**	**50**

Course Objectives	**The course is aimed:** 1. To acquaint with the process of identifying the needs and converting it into the problem. 2. To familiarize the process of solving the problem in a group. 3. To acquaint with the process of applying basic engineering fundamentals to attempt solutions to the problems. 4. To inculcate the process of self-learning and research.
Course Outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Identify problems based on societal /research needs. 2. Apply Knowledge and skill to solve societal problems in a group. 3. Develop interpersonal skills to work as member of a group or leader. 4. Draw the proper inferences from available results through theoretical/ experimental/simulations. 5. Analyse the impact of solutions in societal and environmental context for sustainable development. 6. Use standard norms of engineering practices 7. Excel in written and oral communication. 8. Demonstrate capabilities of self-learning in a group, which leads to life long learning. 9. Demonstrate project management principles during project work.

(A) General Guidelines for Mini Project 1A/ 1B

- Students shall form a group of 3 to 4 students, while forming a group shall not be allowed less than three or more than four students, as it is a group activity.
- Students should do survey and identify needs, which shall be converted into problem statement for mini project in consultation with faculty supervisor/head of department/internal committee of faculties.
- Students hall submit implementation plan in the form of Gantt/PERT/CPM chart, which will cover weekly activity of mini project.
- A log book to be prepared by each group, wherein group can record weekly work progress, guide/supervisor can verify and record notes/comments.
- Faculty supervisor may give inputs to students during mini project activity; however, focus shall be on self-learning.
- Students in a group shall understand problem effectively, propose multiple solution and select best possible solution in consultation with guide/ supervisor.
- Students shall convert the best solution into working model using various components of their domain areas and demonstrate.
- The solution to be validated with proper justification and report to be compiled in standard format of University of Mumbai.

- With the focus on the self-learning, innovation, addressing societal problems and entrepreneurship quality development within the students through the Mini Projects, it is preferable that a single project of appropriate level and quality to be carried out in two semesters by all the groups of the students. i.e. Mini Project-1 in semester III and IV. Similarly, Mini Project 2 in semesters V and VI.
- However, based on the individual students or group capability, with the mentor's recommendations, if the proposed Mini Project adhering to the qualitative aspects mentioned above gets completed in odd semester, then that group can be allowed to work on the extension of the Mini Project with suitable improvements/modifications or a completely new project idea in even semester. This policy can be adopted on case by case basis.

(B) Mini Project 1A/1B–General Guidelines for Execution

Design and Fabrication

e. Initial fabrication of the project by students can be done using standard devices/material/software tools to verify the circuit functionalities Initial project fabrication and testing is expected to be done by soldering/assembling on general purpose PCB/ Bakelite boards or suitable platforms required for the electrical/electronic/digital components. Avoid the use of breadboards.

f. If essential, use of a simulation/ emulation software tools to test and verify the performance of the circuit should be encouraged.

g. Students should prepare the proper drawings (electrical/ mechanical), schematics/ layouts of the project.

h. For final implementation of the circuit, preparation of PCB (if any required) using suitable CAD tools and fabricating the same in the lab is expected.

Devices/ Components/ Systems to be Used:

Students are encouraged to use passive components like resistors, capacitors, inductors etc. If any specialize inductor is not readily available, the fabrication of the same in the lab should be encouraged. Other components like: Transistors, diodes, voltage regulators, logic gates, Op-amps, general purpose microcontroller, DC motors/ AC motors, sensors, actuators, relays etc. (Students may add more components as per the requirement of project).

Testing and analysis of the Project

Students should test the circuit using suitable laboratory equipments like power supply, multi-meter, CRO, DSO etc. In case of any debugging requirement, students should record the problems faced during the testing and solutions sought after for the fault in the circuit.

All the testing results must be well documented in the final project report verifying the functionalities of the propose project.

Use of Reference Material/Literature :

Students are advised to refer Application Notes, research publications & data sheets of various electrical/electronic/digital devices from Texas Instruments, Microchips, International Rectifiers, ST Microelectronics, Philips, NXP and many other manufacturers.

(C) Self-learning and Skill Set Development

Students should be encouraged to develop/ improve their understanding and skill sets by attending various online/offline expert lectures / video lectures/ courses/ webinars/ workshops etc. to facilitate the smooth execution of mini project

1. Understanding passive components viz. resistors, capacitors and inductors from practical point of view: types/ varieties, device packages, applications and cost.
2. Understanding semiconductor components viz. diodes, BJT and JFET/MOSFETs from practical point of view: types/ varieties, device packages, applications and cost.
3. Design principles of simple electrical / electronic circuits with some examples.
4. Selection of switches and circuit protection components.
5. Selection and sizing of wires and conductors.
6. Soldering Practice.
7. Heat-sinking and Enclosure design concepts
8. Overall workmanship while working on the project fabrication.
9. Use of different software tools for design and development of circuits

10. Use of standard as well as advanced laboratory equipments needed for testing of such projects

(D) Suggested List of Application Domains/ Software tools/ Online Repository for Mini Projects

List of key application domains from where students are encouraged to derive Mini Projects topics:

1. Home/Office automation
2. Renewable Energy
3. Energy Conservation
4. Energy Storage
5. Battery Charging and Protection
6. Fire Safety
7. Electrical System Protection
8. Lighting Control
9. Wireless Power Transfer
10. Electrical Components Testing
11. Electrical Parameters Measurement
12. Non-conventional Electricity Generation
13. Laboratory Equipments
14. E-Mobility
15. Video Surveillance Systems
16. Robotics for Hazardous applications
17. Waste Management System 2.
18. Smart City Solutions
19. Smart Classrooms and learning Solutions
20. Smart Agriculture solutions etc.
21. Health/ Biomedical

Students can identify the mini project topics either from above suggested domains or **any other relevant engineering domains**.

Reference Books:

1. P. Horowitz and W. Hill, "The Art of Electronics", 3rd Edition, Cambridge University Press, 2015
2. R. S. Khandpur, "Printed Circuit Board", McGraw-Hill Education; 1st edition, 2005.
3. Simon Monk, "Hacking Electronic: Learning Arduino and Raspberry Pi", McGraw-Hill Education TAB; 2 edition (September 28, 2017).

Suggested Software Tools:

1. LTspice:https://www.analog.com/en/design-center/design-tools-and-calculators/ltspice-simulator.html#
2. Eagle : https://www.autodesk.in/products/eagle/overview
3. OrCAD: https://www.orcad.com/
4. Multisim : https://www.multisim.com/
5. Webbench:http://www.ti.com/design-resources/design-tools-simulation/webench-power-designer.html
6. Tinkercad : https://www.tinkercad.com/
7. Raspbian OS: https://www.raspberrypi.org/downloads
8. Arduino IDE: https://www.arduino.cc/en/main/software

Online Repository:

1. https://www.electronicsforu.com
2. https://circuitdigest.com
3. https://www.electronicshub.org
4. Github

(E) Guidelines for Assessment of Mini Project

Term Work

- The review/ progress monitoring committee shall be constituted by head of departments of each institute. The progress of mini project to be evaluated on continuous basis, minimum two reviews in each semester.
- In continuous assessment focus shall also be on each individual student, assessment based on individual's contribution in group activity, their understanding and response to questions.
- Distribution of Term work marks for both semesters shall be as below;
  - Marks awarded by guide/supervisor based on log book : 10
  - Marks awarded by review committee : 10
  - Quality of Project report : 05

Review/progress monitoring committee may consider following points for assessment based on either one year or half year project as mentioned in general guidelines.

<u>One-year Mini Project:</u>

- In first semester entire theoretical solution shall be ready, including components/system selection and cost analysis. Two reviews will be conducted based on presentation given by students group.
  - First shall be for finalization of problem
  - Second shall be on finalization of proposed solution of problem.
- In second semester expected work shall be procurement of components /systems, building of working prototype, testing and validation of results based on work completed in an earlier semester.
  - First review is based on readiness of building working prototype to be conducted.
  - Second review shall be based on poster presentation cum demonstration of working model in last month of the said semester.

<u>Half-year Mini Project:</u>

- In this case in one semester students' group shall complete project in all aspects including,
  - Identification of need/problem
  - Proposed final solution
  - Procurement of components/systems
  - Building prototype and testing
- Two reviews will be conducted for continuous assessment,
  - First shall be for finalization of problem and proposed solution
  - Second shall be for implementation and testing of solution.

(F) Assessment criteria of Mini Project

Mini Project shall be assessed based on following criteria;

1. Quality of survey/ need identification
2. Clarity of Problem definition based on need.
3. Innovativeness in solutions
4. Feasibility of proposed problem solutions and selection of best solution
5. Cost effectiveness
6. Societal impact
7. Innovativeness
8. Cost effectiveness and Societal impact
9. Full functioning of working model as per stated requirements
10. Effective use of skill sets
11. Effective use of standard engineering norms
12. Contribution of an individual's as member or leader
13. Clarity in written and oral communication

- In **one year, project**, first semester evaluation may be based on first six criteria's and remaining may be used for second semester evaluation of performance of students in mini project.

- In case of **half year project** all criteria's in generic may be considered for evaluation of performance of students in mini project.

Guidelines for Assessment of Mini Project Practical/Oral Examination:

- Report should be prepared as per the guidelines issued by the University of Mumbai.
- Mini Project shall be assessed through a presentation and demonstration of working model by the student project group to a panel of Internal and External Examiners preferably from industry or research organizations having experience of more than five years approved by head of Institution.
- Students shall be motivated to publish a paper based on the work in Conferences/students competitions.

Oral Examination:

Mini Project shall be assessed based on following points;

1. Quality of problem and Clarity
2. Innovativeness in solutions
3. Cost effectiveness and Societal impact
4. Full functioning of working model as per stated requirements
5. Effective use of skill sets
6. Effective use of standard engineering norms
7. Contribution of an individual's as member or leader
8. Clarity in written and oral communication

****

Item No. - 124
AC- 23/7/2020

UNIVERSITY OF MUMBAI

Bachelor of Engineering

in

Electrical Engineering

Second Year with Effect from AY 2020-21

Third Year with Effect from AY 2021-22

Final Year with Effect from AY 2022-23

(REV- 2019 'C' Scheme) from Academic Year 2019 – 20

Under

FACULTY OF SCIENCE & TECHNOLOGY

(As per AICTE guidelines with effect from the academic year 2019–2020)

Item No. - 124
AC- 23/7/2020

UNIVERSITY OF MUMBAI

Syllabus for Approval

Sr. No.	Heading	Particulars
1	Title of the Course	**Second Year B.E. Electrical Engineering**
2	Eligibility for Admission	**After Passing First Year Engineering as per the Ordinance 0.6242**
3	Passing Marks	**40%**
4	Ordinances / Regulations (if any)	**Ordinance 0.6242**
5	No. of Years / Semesters	**8 semesters**
6	Level	~~P.G.~~ / **U.G.**/ ~~Diploma / Certificate~~ (Strike out which is not applicable)
7	Pattern	~~Yearly~~ / **Semester** (Strike out which is not applicable)
8	Status	**New** / ~~Revised~~ (Strike out which is not applicable)
9	To be implemented from Academic Year	**With effect from Academic Year: 2020-2021**

Date

Dr. S. K. Ukarande
Associate Dean, Faculty of Science and Technology
University of Mumbai

Dr Anuradha Muzumdar
Dean, Faculty of Science and Technology
University of Mumbai

Preamble

To meet the challenge of ensuring excellence in engineering education, the issue of quality needs to be addressed, debated and taken forward in a systematic manner. Accreditation is the principal means of quality assurance in higher education. The major emphasis of accreditation process is to measure the outcomes of the program that is being accredited. In line with this Faculty of Science and Technology (in particular Engineering) of University of Mumbai has taken a lead in incorporating philosophy of outcome based education in the process of curriculum development.

Faculty resolved that course objectives and course outcomes are to be clearly defined for each course, so that all faculty members in affiliated institutes understand the depth and approach of course to be taught, which will enhance learner's learning process. Choice based Credit and grading system enables a much-required shift in focus from teacher-centric to learner-centric education since the workload estimated is based on the investment of time in learning and not in teaching. It also focuses on continuous evaluation which will enhance the quality of education. Credit assignment for courses is based on 15 weeks teaching learning process, however content of courses is to be taught in 13 weeks and remaining 2 weeks to be utilized for revision, guest lectures, coverage of content beyond syllabus etc.

There was a concern that the earlier revised curriculum more focused on providing information and knowledge across various domains of the said program, which led to heavily loading of students in terms of direct contact hours. In this regard, faculty of science and technology resolved that to minimize the burden of contact hours, total credits of entire program will be of 170, wherein focus is not only on providing knowledge but also on building skills, attitude and self learning. Therefore in the present curriculum skill based laboratories and mini projects are made mandatory across all disciplines of engineering in second and third year of programs, which will definitely facilitate self learning of students. The overall credits and approach of curriculum proposed in the present revision is in line with AICTE model curriculum.

The present curriculum will be implemented for Second Year of Engineering from the academic year 2020-21. Subsequently this will be carried forward for Third Year and Final Year Engineering in the academic years 2021-22, 2022-23, respectively.

Dr. S. K. Ukarande
Associate Dean
Faculty of Science and Technology
University of Mumbai

Dr Anuradha Muzumdar
Dean
Faculty of Science and Technology
University of Mumbai

Incorporation and Implementation of Online Contents from NPTEL/ Swayam Platform

The curriculum revision is mainly focused on knowledge component, skill based activities and project based activities. Self learning opportunities are provided to learners. In the revision process this time in particular Revised syllabus of 'C ' scheme wherever possible additional resource links of platforms such as NPTEL, Swayam are appropriately provided. In an earlier revision of curriculum in the year 2012 and 2016 in Revised scheme 'A' and 'B' respectively, efforts were made to use online contents more appropriately as additional learning materials to enhance learning of students.

In the current revision based on the recommendation of AICTE model curriculum overall credits are reduced to 171, to provide opportunity of self learning to learner. Learners are now getting sufficient time for self learning either through online courses or additional projects for enhancing their knowledge and skill sets.

The Principals/ HoD's/ Faculties of all the institute are required to motivate and encourage learners to use additional online resources available on platforms such as NPTEL/ Swayam. Learners can be advised to take up online courses, on successful completion they are required to submit certification for the same. This will definitely help learners to facilitate their enhanced learning based on their interest.

Dr. S. K. Ukarande
Associate Dean
Faculty of Science and Technology
University of Mumbai

Dr Anuradha Muzumdar
Dean
Faculty of Science and Technology
University of Mumbai

Preface By BoS

The outcome based course curriculum for the undergraduate degree in Electrical Engineering in Rev.2019 'C' scheme has been chalked out through the thoughtful discussions and deliberations of academic and industry experts. While devising the syllabus content framework, the correct balance between the fundamental / core topics with appropriate mix of topics from the state of the art technologies in electrical and allied domains is attempted. With the increased Industry-Institute interaction and internship programs, students are encouraged to explore the opportunity to improve communication skills, problem solving skill and good team management. These skills shall surely help them to meet the future challenges in their career.

The new course curriculum will also give ample opportunity to the students to work in cross discipline domains to gain the hands on experience through the project based learning facilitated through the various skill based labs, Mini projects, Course projects , Major projects etc. The increased number of department and institute level electives shall facilitate students with the truly choice based learning and skilling in a particular domains.

On behalf of the Board of Studies (BoS) in Electrical Engineering of the University of Mumbai, we seek the active participation from all the stake holders of the engineering education to meet the set outcomes and objectives for the Undergraduate Program in Electrical Engineering.

Board of Studies in Electrical Engineering

Dr. Sushil S. Thale	**: Chairman**
Dr. B. R. Patil	**: Member**
Dr. S. R. Deore	**: Member**
Dr. B. B. Pimple	**: Member**
Dr. Nandkishor Kinhekar	**: Member**

Semester IV

Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	Pract.	Tut.	Total
EEC401	Engineering Mathematics-IV	3	--	1	3	--	1	4
EEC402	Electrical AC Machines-I	3	--	--	3	--	--	3
EEC403	Digital Electronics	3	--	--	3	--	--	3
EEC404	Power Electronic Devices and Circuits	3	--	--	3	--	--	3
EEC405	Electric and Hybrid Electric Vehicles	3	--	--	3	--	--	3
EEL401	Electrical AC Machines Lab I	--	2	--	--	1	--	1
EEL402	Python Programming Lab	--	2	--	--	1	--	1
EEL403	Electronics Lab II	--	2	--	--	1	--	1
EEL404	SBL-II : PCB Design and Fabrication Lab	--	4	--	--	2	--	2
EEM401	Mini Project – 1B	--	4$	--	--	2	--	2
Total		**15**	**14**	**1**	**15**	**7**	**1**	**23**

Examination Scheme

Course Code	Course Name	Theory					Term Work	Pract/ oral	Total
		Internal Assessment			End Sem. Exam.	Exam. Duration (in Hrs)			
		Test I	Test II	Avg.					
EEC401	Engineering Mathematics-IV	20	20	20	80	3	25	--	125
EEC402	Electrical AC Machines-I	20	20	20	80	3	--	--	100
EEC403	Digital Electronics	20	20	20	80	3	--	--	100
EEC404	Power Electronic Devices and Circuits	20	20	20	80	3	--	--	100
EEC405	Electric and Hybrid Electric Vehicles	20	20	20	80	3	--	--	100
EEL401	Electrical AC Machines Lab-I	--	--	--	--	--	25	25	50
EEL402	Python Programming Lab	--	--	--	--	--	25	25	50
EEL403	Electronics Lab-II	--	--	--	--	--	25	25	50
EEL404	SBL-II: PCB Design and Fabrication Lab	--	--	--	--	--	50	--	50
EEM401	Mini Project -1B	--	--	--	--	--	25	25	50
Total		**--**	**--**	**100**	**400**	**--**	**175**	**100**	**775**

$ indicates work load of Learner (Not Faculty), for Mini Project

SBL: Skill Based Lab

Students group and load of faculty per week.

Mini Project 1A / 1B: Students can form groups with minimum 3 (Three) and not more than 4 (Four)
Faculty Load: 1 hour per week per four groups

Semester-IV								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEC401	**Engineering Mathematics-IV**	**03**	**-**	**01**	**03**	**-**	**01**	**04**

Examination Scheme								
Theory					Term Work/Practical/Oral			Total
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract.	Oral	
Test-I	Test-II	Average						
20	**20**	**20**	**80**	**03 Hrs**	**25**	**-**	**-**	**125**

Pre-requisite: Engineering Mathematics-I, Engineering Mathematics-II, Engineering Mathematics-III, Binomial Distribution.

Course Objectives	**The course is aimed:** 1. To study the line and contour integrals and expansion of complex valued function in a power series. 2. To understand the basic techniques of statistics for data analysis, Machine learning and AI. 3. To study the probability distributions and expectations. 4. To acquaint with the concepts of vector spaces used in the field of machine learning and engineering problems. 5. To familiarize with the concepts of Quadratic forms and Singular value decomposition. 6. To learn the concepts of Calculus of Variations.
Course Outcomes	**On successful completion of course learner/student will be able to:** 1. Use the concepts of Complex Integration for evaluating integrals, computing residues & evaluate various contour integrals. 2. Demonstrate the use of Correlation and Regression to the engineering problems in data science, machine learning and AI. 3. Illustrate understanding of the concepts of probability and expectation for getting the spread of the data and distribution of probabilities. 4. Apply the concept of vector spaces and orthogonalization process in Engineering Problems. 5. Use the concept of Quadratic forms and Singular value decomposition in various Engineering applications. 6. Find the extremals of the functional using the concept of Calculus of variation.

Module	Detailed Contents	Hours.
1	**Module: Complex Integration:** 1.1 Line Integral, Cauchy's Integral theorem for simple connected and multiply connected regions (without proof), Cauchy's Integral formula (without proof). 1.2 Taylor's and Laurent's series (without proof). 1.3 Definition of Singularity, Zeroes, poles of *f(z)*, Residues, Cauchy's Residue Theorem (without proof). **Self-learning Topics:** Application of Residue Theorem to evaluate real integrations, Z-Transform.	**07**

2	**Module: Statistical Techniques:** 2.1 Karl Pearson's Coefficient of correlation (r) 2.2 Spearman's Rank correlation coefficient (R) (repeated and non-repeated ranks) 2.3 Lines of regression. 2.4 Fitting of first and second degree curves. **Self-learning Topics:** Covariance, fitting of exponential curve.	**06**
3	**Module: Probability Distributions:** 2.1 Baye's Theorem, Random variable: Probability distribution for discrete and continuous random variables, Density function and distribution function. 3.2 Expectation, mean and variance. 3.3 Probability distribution: Poisson & normal distribution. **Self-learning Topics:** Moments, Moment Generating Function, Applications of Probability Distributions in Engineering.	**07**
4	**Module: Linear Algebra: Vector Spaces:** 4.1 Vectors in n-dimensional vector space, norm, dot product, The Cauchy-Schwarz inequality (with proof), Unit vector. 4.2 Orthogonal projection, Orthonormal basis, Gram-Schmidt process for vectors. 4.3 Vector spaces over real field, subspaces. **Self-Learning Topics**: Linear combinations, linear Dependence and Independence, QR decomposition.	**06**
5	**Module: Linear Algebra: Quadratic Forms:** 5.1 Quadratic forms over real field, Linear Transformation of Quadratic form, Reduction of Quadratic form to diagonal form using congruent transformation. 5.2 Rank, Index and Signature of quadratic form, Sylvester's law of inertia, Value- class of a quadratic form-Definite, Semidefinite and Indefinite. 5.3 Reduction of Quadratic form to a canonical form using congruent transformations. 5.4 Singular Value Decomposition. **Self-learning Topics:** Orthogonal Transformations**,** Applications of Quadratic forms and SVD in Engineering.	**07**
6	**Module: Calculus of Variations:** 6.1 Euler-Lagrange equation (Without Proof), When F does not contain y, When F does not contain x, When F contains x, y, y'. 6.2 Isoperimetric problems- Lagrange Method. 6.3 Functions involving higher order derivatives: Rayleigh-Ritz Method. **Self-Learning Topics:-** Brachistochrone Problem, Variational Problem, Hamilton Principle, Principle of Least action, Several dependent variables.	**06**

Term Work:

General Instructions:

1. Students must be encouraged to write at least 6 class tutorials on entire syllabus.
2. A group of 4-6 students should be assigned a self-learning topic. Students should prepare a presentation/problem solving of 10-15 minutes. This should be considered as mini project in Engineering Mathematics. This project should be graded for 10 marks depending on the performance of the students.

The distribution of Term Work marks will be as follows –

1.	Attendance (Theory and Tutorial)	05 marks
2.	Class Tutorials on entire syllabus	10 marks
3.	Mini project	10 marks

Assessment:

Internal Assessment Test:
Assessment consists of two class tests of 20 marks each. The first-class test (Internal Assessment I) is to be conducted when approx. 40% syllabus is completed and second class test (Internal Assessment II) when additional 40% (approx.)syllabus is completed. Duration of each test shall be one hour.

End Semester Theory Examination:
1. Question paper will comprise of total 06 questions, each carrying 20 marks.
2. Total 04 questions need to be solved.
3. Question No: 01 will be compulsory and based on entire syllabus wherein 4 sub-questions of 5 marks each will be asked.
4. Remaining questions will be randomly selected from all the modules.
5. Weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

Books Recommended:

Text Books:

1. Complex Variables and Applications, Brown and Churchill, McGraw-Hill education.
2. Probability, Statistics and Random Processes, T. Veerarajan, McGraw-Hill education.
3. Advanced engineering mathematics, H.K. Das, S. Chand, Publications.
4. Higher Engineering Mathematics, B. V. Ramana, Tata Mc-Graw Hill Publication
5. Advanced Engineering Mathematics, R. K. Jain and S. R. K. Iyengar, Narosa publication
6. Advanced Engineering Mathematics, Wylie and Barret, Tata Mc-Graw Hill.
7. Beginning Linear Algebra, Seymour Lipschutz Schaum's outline series, McGraw Hill Publication
8. Higher Engineering Mathematics, Dr. B. S. Grewal, Khanna Publication

Semester-IV								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEC402	**Electrical AC Machines - I**	**03**	**-**	**-**	**03**	**-**	**-**	**03**

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract.	Oral	
Test-I	Test-II	Average						
20	**20**	**20**	**80**	**03 Hrs**	**-**	**-**	**-**	**100**

Course Objectives	**The course is aimed:** 1. To impart knowledge of performance and operation of an induction motor. 2. To impart the knowledge of working principle, operations, performance and applications of single phase and three phase Transformers.
Course Outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Illustrate working principle and performance of single phase transformer under different operating conditions 2. Understand working principle of autotransformer. 3. Analyze various types of connections and performance of three phase transformer under various conditions. 4. Demonstrate working principle and evaluate the performance of three phase induction motor under various operating conditions. 5. Exemplify various starting methods and speed control of three phase induction motor.

Module	Detailed Contents	Hours
1	**Single phase Transformer:** Review of working principle, EMF equation and Equivalent Circuit, Phasor diagram (Resistive, Inductive and capacitive load), voltage regulation, Losses and Efficiency, Condition for Maximum Efficiency, Parallel Operation: No load Operation, On load Operation: - Equal Voltage Operation and Unequal Voltage Operation, Testing of Transformer: OC and SC test, Sumpner's Test	**07**
2	**Autotransformer:** Working, Advantages of Autotransformer over two winding Transformer, Disadvantages, Isolation Transformer working and its applications.	**02**
3	**Three Phase Transformer:** Constructional details, Principle of operation, Connections and Phasor groups, Parallel operation, Excitation Phenomenon in transformers, Harmonics in three phase transformers, Suppression of harmonics, Oscillating neutral phenomenon, Switching intransient phenomenon, Open delta or V - connection, Three phases to two phase conversion (Scott connection).	**08**
4	**Three Phase Induction Motor:** Review of Constructional details and Principle of operation, Slip, Rotor emf and frequency, current and power, Power stages, Phasor diagram, Equivalent circuit, Torque-speed characteristics in braking ,motoring and generating regions, Losses and efficiency, No load and blocked rotor test, Circle diagram, Applications.	**10**

5	**Starting and Speed control of Three Phase Induction Motor:** Need of starter, Types of starters: Direct On Line (DOL) starter, Rotor resistance starter, Autotransformer and Star delta starters, Speed control: Voltage control, Frequency control, Pole changing method, V/f control.	**06**
6	**Single phase Induction Motor**: Principle of operation (Review), Double field revolving theory, Equivalent circuit of single phase induction motor, Determination of equivalent circuit parameters from no load and block rotor test, Staring methods, Split phase starting- Resistance spilt phase, capacitor split phase, capacitor start and run, shaded pole starting, Applications of 1ϕ IM	**06**

Assessment:

Internal Assessment Test:

Assessment consists of two class tests of 20 marks each. The first-class test (Internal Assessment I) is to be conducted when approx. 40% syllabus is completed and second class test (Internal Assessment II) when additional 40% (approx..) syllabus is completed. Duration of each test shall be one hour.

End Semester Theory Examination:

1. Question paper will comprise of total 06 questions, each carrying 20 marks.
2. Total 04 questions need to be solved.
3. Question No: 01 will be compulsory and based on entire syllabus wherein 4 sub-questions of 5 marks each will be asked.
4. Remaining questions will be randomly selected from all the modules.
5. Weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

Books Recommended:

Text Books:

1. Bimbhra P.S., *Electric Machinery* , Khanna Publisher
2. Bimbhra P.S., *Generalized Machine Theory*, Khanna Publisher
3. V. K. Mehta, *Principles of Electrical Machines*, S Chand Publication

Reference Books:

1. M.G. Say, Performance and Design of Alternating Current Machines, CBS Pub.
2. Ashfaq Husain, *Electric Machines***,** Dhanpat Rai and Co.
3. A.E. Fitzgerald, Kingsly, Stephen., *Electric Machinery*, Tata McGraw Hill

NPTEL/ Swayam Course:

1. **Course: Electrical Machines – II By Prof. Tapas Kumar Bhattacharya (IIT Kharagpur)**
   https://nptel.ac.in/noc/courses/noc19/SEM1/noc19-ee01/
2. **Course: Electrical Machines By Prof. Bhuvaneshwari (IIT Delhi)**
   https://swayam.gov.in/nd1_noc19_ee69/preview

Semester-IV								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEC403	**Digital Electronics**	**03**	**-**	**-**	**03**	**-**	**-**	**03**

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract.	Oral	
Test-I	Test-II	Average						
20	**20**	**20**	**80**	**03 Hrs**	**-**	**-**	**-**	**100**

Course Objectives	**The course is aimed:** 1. To understand working of logic families and logic gates. 2. To study the combinational and sequential logic circuits. 3. To understand Analog to Digital and Digital to Analog conversions. 4. To introduce ROM as Programmable Logic Device.
Course Outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Perform conversion of various number systems 2. Understand working of logic families and logic gates. 3. Design and implement combinational circuits. 4. Design and implement sequential circuits. 5. Understand the process of Analog to Digital conversion and Digital to Analog conversion. 6. Illustrate the use of PLDs to implement the given logical problem.

Module	Detailed Contents	Hours
1	**Fundamentals of Digital Systems and Logic families:** Number formats: Binary, signed binary, Octal, hexadecimal, BCD and their basic math operations (addition and subtraction) Logic gates: Digital signals, digital circuits, AND, OR, NOT, NAND, NOR and Exclusive-OR operations, Boolean Algebra, Specifications of Digital IC Logic Families: TTL, CMOS logic families, Comparison of TTL and CMOS, Interfacing of TTL and CMOS, Tri-state logic	**07**
2	**Combinational Digital Circuits:** Design & Simplification of logic functions: K-map representation, simplification of logic functions using K-map (upto 4 variables), Minterm, maxterm, SOP and POS implementation, realization of logic function using universal gates Binary Arithmetic circuits: Adder and Subtractor (Half and Full), Multiplier, 2 bit comparators, Multiplexer, de-multiplexer, decoder Designing code converter circuit: binary to gray, Gray to Binary, Multiplexer (ULM), De-multiplexers, BCD to 7 segment	**10**
3	**Sequential Digital Circuits** Comparison of combinational & sequential circuit, Flip-flops -SR, JK,T, D, Master Slave JK, Counters-Modulus of counter, Design of Synchronous, Asynchronous counters, Ripple Up/Down Counter, Ring counter, Shift Registers –Right and left shift registers, Serial to parallel converter, parallel to serial converter, applications of counters.	**06**
4	**A/D and D/A Converters:** Digital to Analog converter: Weighted resistor converter, R-2R ladder D/A converter, examples of D/A converter ICs.	**05**

	Analog to Digital converter: sample and hold circuit, Quantization and encoding, successive approximation A/D converter, dual slope A/D converter, voltage to frequency and voltage to time conversion, specifications of A/D converters, example of A/D converter ICs	
5	**Semiconductor Memories:** Classification and characteristics of memories, Memory organization and operation, expanding memory size- Memory mapping and address decoding , sequential memory, read only memory (ROM), read and write memory (RAM), content addressable memory (CAM), commonly used memory chips	**06**
6	**Programmable Logic Devices:** ROM as a programmable logic device, programmable logic array, programmable array logic, Complex Programmable Logic Devices (CPLDs), Field Programmable Gate Array (FPGA)	**05**

Assessment:

Internal Assessment Test:

Assessment consists of two class tests of 20 marks each. The first-class test (Internal Assessment I) is to be conducted when approx. 40% syllabus is completed and second class test (Internal Assessment II) when additional 40% (approx.) syllabus is completed. Duration of each test shall be one hour.

End Semester Theory Examination:

1. Question paper will comprise of total 06 questions, each carrying 20 marks.
2. Total 04 questions need to be solved.
3. Question No: 01 will be compulsory and based on entire syllabus wherein 4 sub-questions of 5 marks each will be asked.
4. Remaining questions will be randomly selected from all the modules.
5. Weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

Books Recommended:

Text Books:

1. Anand Kumar, “Fundamentals of Digital Circuits”, Prentice Hall India, 2016
2. R. P. Jain, “Modern Digital Electronics” Tata McGraw Hill Education, 2009
3. Morris. M. Mano, “Digital Logic and Computer design”, Pearson Education India, 2016
4. Alan b. Marcovitz, “Introduction to logic Design”, McGraw Hill International 2002.
5. Malvino & Leach, Digital principal and Application”, Tata McGraw Hill, 1991

NPTEL/ Swayam Course:

1. **Course: Digital Electronic Circuits By Prof. Goutam Saha (IIT Kharagpur)**
   https://swayam.gov.in/nd1_noc20_ee32/preview
2. **Course: Digital Circuits and Systems - Video course By Prof. S. Srinivasan (IIT Madras)**
   https://nptel.ac.in/courses/117/106/117106086/

Semester-IV								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEC404	**Power Electronic Devices and Circuits**	**03**	**-**	**-**	**03**	**-**	**-**	**03**

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract.	Oral	
Test-I	Test-II	Average						
20	**20**	**20**	**80**	**03 Hrs**	**-**	**-**	**-**	**100**

Course Objectives	**The course is aimed:** 1. To impart knowledge about various power semiconductor devices related to its characteristics, ratings, protection and facilitate selection of semiconductor devices for various applications. 2. To introduce different power conversion topologies such as ac to dc, dc to dc, dc to ac and the underlying principles of converter operation aiding to analyse their performance. 3. To keep abreast with the latest technologies and research going on in different domains related to power electronics.
Course Outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Understand the basic operation and characteristics of various semi controllable and fully controllable devices 2. Analyse various single phase and three phase power converter circuits and understand their applications. 3. Analyse dc to dc converter circuits and their applications. 4. Identify and describe various auxiliary circuits and requirements in power electronics applications such as gate driver circuit, snubber circuits and heat sinks. 5. Apply the basic concepts to select devices and converters for various applications

Module	Detailed Content	Hours
1	**Thyristors:** Basic operation of silicon controlled rectifier, Static characteristics, two transistor analogy, Dynamic characteristics, Firing circuits (R,RC, Ramp triggering using UJT), Commutation circuits, Protection circuit of SCR. **Self study topic**: Other devices of Thyristor family	**07**
2	**Power semiconductor devices:** Basic operation and characteristics of power diodes, power BJTs, power MOSFETs, IGBTs, Safe Operation Area (SOA) for each devices, Silicon Carbide (SiC) and GaN devices, Comparison of devices, selection of devices for various applications, Conduction and switching losses.	**06**
3	**Controlled Rectifiers:** Single phase half wave rectifiers, full wave rectifiers (mid-point and bridge configuration) for R and R-L load, freewheel diode, Rectification and inversion mode of single phase fully controlled rectifier, single phase dual converter, Three phase semi converter and full converter with R load, Applications, calculation of output voltage, single phase PWM rectifier, basic working principle and applications.	**08**
4	**Inverter:** Classification based on source and power level, Single phase bridge Inverters (VSI), Performance parameters, Three phase VSI (120° and 180° conduction mode), Voltage	**06**

	control of single phase inverters- PWM techniques-Single PWM, Multiple PWM, Sinusoidal PWM, Basics of Space vector modulation, Single phase current source inverters (CSI), comparison of VSI and CSI.	
5	**DC to DC Converter**: Introduction, Switching mode regulators – Buck, Boost, Buck-Boost, bidirectional dc to dc converters, all with resistive load and only CCM mode, Applications: Power Factor Correction Circuits, LED lamp driver.	**07**
6	**Auxiliary Circuits**: Types of drivers-level shifters, bootstrap drivers, isolated drivers, Gate Drive circuitry for Power Converters, methods of current and voltage measurement, snubber circuits and heat sinks.	**05**

Assessment:

Internal Assessment Test:

Assessment consists of two class tests of 20 marks each. The first-class test (Internal Assessment I) is to be conducted when approx. 40% syllabus is completed and second class test (Internal Assessment II) when additional 40% (approx.) syllabus is completed. Duration of each test shall be one hour.

End Semester Theory Examination:

1. Question paper will comprise of total 06 questions, each carrying 20 marks.
2. Total 04 questions need to be solved.
3. Question No: 01 will be compulsory and based on entire syllabus wherein 4 sub-questions of 5 marks each will be asked.
4. Remaining questions will be randomly selected from all the modules.
5. Weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

Books Recommended:

Text Books:

1. M. H. Rashid, *Power Electronics: Circuits, Devices, and Applications*, Pearson Education, 2009.
2. N. Mohan and T. M. Undeland, *Power Electronics: Converters, Applications and Design*, John Wiley & Sons, 2007.
3. R.W. Erickson and D. Maksimovic, *Fundamentals of Power Electronics*, Springer Science & Business Media, 2007.
4. L. Umanand, *Power Electronics: Essentials and Applications*, Wiley India, 2009.
5. P.C Sen., *Modern Power Electronics*, Wheeler publishing Company, 1st Edition, 2005
6. Alok Jain, *Power Electronics: Devices, Circuits and Matlab Simulations*, Penram Int. 2010
7. B. Jayant Baliga, *Silicon Carbide Power Devices*, World Scientific, 2005.

Reference Books:

1. C.W. Landers, *Power Electronics*, McGraw Hill, 1993
2. Ashfaq Ahmed, *Power Electronics for Technology*, Pearson, 1998
3. Joseph Vithayathil, *Power Electronics*, Tata McGraw hill, 1995.
4. P. Friedrichs, T. Kimoto, L. Ley and G. Pensl, *Silicon Carbide, Volume 2: Power Devices and Sensors*, Wiley Publications, 2011.
5. Dokić, Branko L. and Blanuša, Branko, *Power Electronics Converters and Regulators* Springer International Publishing, 2015

NPTEL/ Swayam Course:

1. **Course: Advance Power Electronics And Control – Prof. Avik Bhattacharya (IIT Roorkee) https://nptel.ac.in/courses/108/107/108107128/**
2. **Course: Power Electronics By Prof. G. Bhuvaneshwari (IIT Delhi) https://swayam.gov.in/nd1_noc20_ee97/preview**

Semester IV								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEC405	**Electric and Hybrid Electric Vehicle**	**03**	**-**	**-**	**03**	**-**	**-**	**03**

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract.	Oral	
Test-I	Test-II	Average						
20	**20**	**20**	**80**	**03 Hrs**	**-**	**-**	**-**	**100**

Course Objectives	**The course is aimed:** 1. To learn the history of electric hybrid electric vehicles (EV & HEV) and emphasize the need and importance of EV-HEV for sustainable future. 2. To study the fundamental concepts and principles of electric and hybrid electric vehicles drive train topologies 3. To develop a thorough understanding of the key elements of EV/HEV: Electric Machines for Propulsion Applications and Energy Sources 4. To model, analyze and design electric and hybrid electric vehicles drive train and to understand energy management strategies
Course outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Identify and describe the history and evolvement of electric & hybrid electric vehicles. 2. Identify and describe the principles of various EV/HEVs drive train topologies. 3. Select electric propulsion system components for EV/HEV drives for the desirable performance and control**.** 4. Compare and evaluate various energy sources and energy storage components for EV/HEV. 5. Model, analyze and design EV/HEV drive train with energy management strategies**.** 6. Recognize the need to adapt and engage in operations EV/HEV for sustainable transportation system.

Module	Detailed Contents	Hours
1	**Introduction:** Basics of vehicles mechanisms**,** history of electric vehicles (EV) and hybrid electric vehicles (HEV), need and importance of EV and HEV, Power/Energy supplies requirements for EV/HEV applications. State of the art and Indian and global scenario in EV/HEV	**04**
2	**Drive-train Topologies:** Various electric drive-train topologies, basics of hybrid traction system, various hybrid drive-train topologies, power flow control in drive-train topologies, fuel efficiency analysis.	**07**
3	**DC and AC Machines for Propulsion Applications:** Electric system components for EV/HEV, suitability of DC and AC machines for EV/HEV applications, AC and DC Motor drives.	**05**
4	**Energy Sources for EV/HEV:** Requirements of energy storage in EV/HEV: batteries, fuel cells, flywheels and ultra-capacitors as energy sources for EV/HEV, characteristics and comparison of	**10**

	energy sources for EV/HEV, hybridization of different energy sources. EV battery chargers: AC and DC, Fast chargers and related standards	
5	**Drive-train Modelling and Design Considerations :** Modeling and analysis of EV/HEV drive train: Total tractive force calculation, sizing of motor, and design considerations for power electronics drive.	**08**
6	**Energy Management Strategies and Energy Efficiency:** EV/HEV energy management strategies, classification and comparison of various energy management strategies. Basic EV AC and DC Chargers, G2V and V2G concept.	**05**

Self-study: Testing and Evaluation Standards for EV & HEV available on Automotive Research Association of India (ARAI) website: https://emobility.araiindia.com/standards/

Assessment:

Internal Assessment Test:

Assessment consists of two class tests of 20 marks each. The first-class test (Internal Assessment I) is to be conducted when approx. 40% syllabus is completed and second class test (Internal Assessment II) when additional 40% (approx.) syllabus is completed. Duration of each test shall be one hour.

End Semester Theory Examination:

1. Question paper will comprise of total 06 questions, each carrying 20 marks.
2. Total 04 questions need to be solved.
3. Question No: 01 will be compulsory and based on entire syllabus wherein 4 sub-questions of 5 marks each will be asked.
4. Remaining questions will be randomly selected from all the modules.
5. Weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

Books Recommended:

Text Books:

1. I. Hussein, *Electric and Hybrid Vehicles: Design Fundamentals*, CRC Press, 2003.
2. M. Ehsani, Y. Gao, S.E. Gay and Ali Emadi, *Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design*, CRC Press. 2005
3. Sheldon Williamsom, *Energy Management Strategies for Electric and Plug-in Hybrid Vehicles*, Springer 2013
4. J. Larminie and J. Lowry, *Electric Vehicle Technology Explained*, Wiley, 2003
5. C. MI, M. Abul and D. W. Gao, *Hybrid Electrical Vehicle Principles and Application with Practical Perspectives,* Wiley 2011

Reference Books:

1. N.Mohan, T.M.Undeland, and W.P Robbins, *Power Electronics, Converters, Applications & Design,* Wiley India Pvt. Ltd., 2003
2. B. K Bose*, Modern Power Electronics and AC Drives*, Pearson Education 2002
3. Robert A. Huggins, *Energy Storage*, Springer 2010

NPTEL/ Swayam Course:

1. **Course: Intro. to Hybrid and Electric Vehicles - Prof. Praveen Kumar & Prof. S. Majhi (IIT Guwahati): https://nptel.ac.in/courses/108/103/108103009/**
2. **Course: Electric Vehicles - Part 1 By Prof. Amit Kumar Jain (IIT Delhi) https://nptel.ac.in/courses/108/102/108102121/**

Semester-IV								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEL401	**Electrical AC Machines Lab-I**	-	**02**	**-**	**-**	**01**	**-**	**01**

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract./ Oral	Oral	
Test-I	Test-II	Average						
-	**-**	**-**	**-**	**-**	**25**	**25**	**-**	**50**

Course Objectives	**To impart the knowledge on :** 1. Construction, principle of operation, design, performance and applications of single and three phase Transformers 2. Construction, principle of operation, design, performance and applications of single and three phase Induction Motors.
Course Outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Demonstrate the working principles and types of connections of 1φ and 3φ transformers. 2. Analyze the performance of 3φ transformer under various operating conditions. 3. Evaluate the performance of 3φ induction motor by carrying no load test , blocked rotor test and load test 4. Illustrate the operation of various type of 3φ induction motor starters. 5. Illustrate different methods of speed control and braking of 3φ induction motors.

Syllabus: Same as **EEC402- Electrical AC Machines-I**

Suggested List of Laboratory Experiments: Minimum eight experiments need to be performed.

1. Study of transformer connections**.**
2. Sumpner's test on single phase transformer
3. Open circuit & short circuit test on three phase transformer.
4. Parallel operation of transformers.
5. Scott connection of transformer.
6. Open Delta (V) connection of transformer
7. Load Test on three phase squirrel cage induction motor.
8. Load test on three phase slip ring induction motor.
9. No load and Blocked rotor test on three phase induction motor. (Determination of equivalent circuit parameters)
10. Separation of no load losses of three phase induction motor.
11. Performance analysis of three phase induction motor using circle diagram.
12. Study of different types of induction motor starters.
13. Speed control by v/f method.
14. Study of induction motor braking methods
15. Open circuit and short circuit test on single phase transformer and find equivalent circuit parameters.
16. No load and block rotor test on single phase induction motor.
17. Load test on single phase induction motor.

Any other experiments based on syllabus which will help students to understand topic/concept.

Note:

Students and teachers are encouraged to use the 'Virtual Labs' (an MHRD Govt. of India Initiative) whose links are as given below. The remote-access to Labs in various disciplines of Science and Engineering is available. Students can conduct experiments which would help them in learning basic and advanced concepts through remote experimentation.

Virtual Lab Website Reference

1. http://vlab.co.in/broad-area-electrical-engineering
2. http://vlab.co.in/broad-area-electronics-and-communications

Term work:

Term work shall consist of minimum 8 experiments. The distribution of marks for term work shall be as follows:

Laboratory performance	: 10 marks
Journal	: 10 marks
Attendance	: 05 marks

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

Practical / Oral Examination:

Practical exam will be based on all the laboratory experiments carried out and Oral examination will be based on entire syllabus of **EEC402-Electrical AC Machines-I**
The distribution of marks for practical examination shall be as follows:

- Practical Exam : 15 marks
- Oral Exam : 10 marks

Semester-IV								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEL402	**Python Programming Lab**	-	**02**	**-**	**-**	**01**	**-**	**01**

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract./ Oral	Oral	
Test-I	Test-II	Average						
-	**-**	**-**	**-**	**-**	**25**	**25**	**--**	**50**

Course Objectives	**The course is aimed:** 1. To introduce core programming basics and program design with functions using Python programming language. 2. To study the use of procedural statements like assignments, conditional statements, loops and function calls. 3. To learn the supported data structures like lists, dictionaries and tuples in Python. 4. To describe the need for Object-oriented programming concepts in Python.
Course Outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Describe the numbers, Math functions, Strings, List, Tuples and Dictionaries in Python 2. Express different Decision Making statements and Functions 3. Illustrate the skill of object oriented programming in Python to develop applications in electrical engineering 4. Understand different File handling operations 5. Understand the design of GUI Applications in Python and evaluate different database operations

Prerequisite: Basic Programming syntax of Java/C.

Module	Detailed Contents	Hours
1	**Basics of Python** **Theory:** Numbers in Python, Basic & Built-in Math functions, Number Formats, Strings, Quotes, print () Function, Assigning Values to Names & Changing Data Through Names, Copying Data, Tuples-Unchanging Sequences of Data, Lists-Changeable Sequences of Data; Dictionaries - Groupings of Data Indexed by Name, Special String Substitution Using Dictionaries, Arrays, Treating a String Like a List, Special Types, Ranges of Sequences, Working with Sets, Arrays. **Lab Experiment:** Write python programs to understand Expressions, Variables, Quotes, Basic Math operations, Strings: Basic String Operations & String Methods, List, Tuples, Dictionaries, Arrays (**Minimum Two Programs** based on math operations, Strings and List/Tuples/ Dictionaries)	**05**
2	**Decision Making and Functions:** **Theory:** If statement, if-elif-else, Repetition using while loop, for loop, break statement, Handling Errors- try: statement, except: statement, Functions-Grouping Code under a Name, defining a Function, function in the function, Checking & Setting Your Parameters, Calling Functions from within Other Functions, Functions Inside of Functions, Layers of Functions	**05**

	Lab Experiment: Write python programs to understand different decision making statements and Functions. (**Minimum Two Programs** based on Decision making, Looping Statements and Functions)	
3	**Object Oriented Programming using Python programming:** **Theory**: Creating a Class, Self Variables, Constructors, Types of Methods, Inner Classes, Constructors in Inheritance, Polymorphism, Interfaces in Python. Exceptions Handling: Errors in a Python Program, Exceptions, Exception Handling, Types of Exceptions. **Lab Experiment:** Write python programs to understand different Object oriented features in Python (**Minimum Two programs** based on a) Classes & objects, b) Constructors, c) Inheritance & Polymorphism, d) Exception handling.	**05**
4	**Advanced Python Libraries:** **Introduction to Objects and Functions** of a. Numpy - core library for scientific computing b. Pandas - fast, powerful, flexible and easy to use open source data analysis and manipulation tool c. MatplotLib - comprehensive library for creating static, animated, and interactive visualizations d. SciPy - ecosystem of open-source software for mathematics, science, and engineering **Lab Experiment:** Write **Minimum Two programs** python programs to understand different functionalities exposed by each of the above libraries.	**07**
5	**GUI Programming and Databases Theory**: **GUI Programming** - Writing a GUI with Python: GUI Programming Toolkits, Creating GUI Widgets with Tkinter, Creating Layouts, Radio Buttons and Checkboxes, Dialog Boxes. Database Access - Python's Database Connectivity, Types of Databases Used with Python, Mysql database Connectivity with Python, Performing Insert, Deleting & Update operations on database **Lab Experiment:** Students should be given demonstration of GUI designing and database operations.	**04**

Term work:

Term work shall consist of minimum 08 experiments. The distribution of marks for term work shall be as follows:

Laboratory Performance : 20 marks
Attendance : 05 marks

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

Practical/ Oral Examination:

Practical / Oral examination will be based on all the lab experiments carried out and the entire syllabus of EEL402- Python Programming Lab. The distribution of marks for practical examination shall be as follows: Practical Exam- 15 marks and Oral Exam -10 marks.

Reference Books:

1. Mark Lutz, *Learning Python*, O Reily, 4thEdition, 2009,
2. Mark Lutz, *Programming Python*, O Reily, 4thEdition, 2010
3. Tim Hall and J-P Stacey, *Python 3 for Absolute Beginners*, 2009.
4. Magnus Lie Hetland, *Beginning Python: From Novice to Professional*, 2nd Edition, 2009.
5. Wesley J. Chun, *Core Python Programming*, Second Edition, Pearson
6. Jeeva Jose, *Taming Python by Programming*, Khanna Publishing House
7. J. Jose, *Introduction to Computing and Problem Solving with Python*, Khanna Publications
8. Seema Thareja, *Python Programming*, Pearson

Semester-IV								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEL403	**Electronics Lab II**	-	**02**	**-**	**-**	**01**	**-**	**01**

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract./ Oral	Oral	
Test-I	Test-II	Average						
-	**-**	**-**	**-**	**-**	**25**	**25**	**-**	**25**

Course Objectives	**The course is aimed:** 1. To introduce the basic building blocks and applications Digital logic devices. 2. To illustrate the students to practical circuits based on the power electronics devices used in various applications.
Course Outcomes	**Upon successful completion of this course, the learner will be able to** 1. Use various digital logic Gates, flip-flops and counters for various applications 2. Build, design and analyse sequential / combinational circuits. 3. Understand the operation various power electronics devices and circuits 4. Use power converters for various real life applications 5. Realize the implementation of digital interface with power electronics converters

Syllabus: Same as that of Course **EEC403- Digital Electronics** and **EEC404-Power Electronics Devices and Circuits.**

Suggested List of Laboratory Experiments: Minimum four experiments from each Group A and Group B (total minimum eight) need to be performed.

Group A: EEC405- Digital Electronics

1. SOP and POS Minimization (different problem statement for each student)
2. Characteristics of TTL and MOS logic family
3. Implementation of counters with flip-flops.
4. Constructing flip-flops using all NAND gates.
5. Designing a mod N counter where N <14 using J K flip-flops and D flip-flops.
6. Design of a ripple counter
7. Design two bit comparator using gate ICs.
8. Study of Analog to Digital Converter
9. Study of Digital to Analog Converter
10. Any one of the following
    (i) Full Adder using Gates and using Decoder or a Multiplexer.
    (ii)Using a shift register as a sequence generator.

Group B: EEC403-Power Electronics Devices and Circuits:

1. Study of I-V characteristics of Thyristors (SCR/Triac)
2. Study of switching characteristics of Power BJT/ Power MOSFET/ IGBT
3. Implementation of Single phase Half wave and Full wave rectifiers
4. Study of single phase PWM rectifier
5. Implementation and testing of SPWM VSI.
6. Design of IGBT gate drivers circuit
7. Design and Implementation of DC-DC Buck converter

8. Design and Implementation of DC-DC Boost converter
9. Implementation and testing of LED driver circuit
10. Study of current and voltage measurement circuits in switching converters
11. Study of Analog to Digital Converter

Any other experiments based on syllabus which will help students to understand topic/concept.

Note:

Students and teachers are encouraged to use the 'Virtual Labs' (an MHRD Govt. of India Initiative) whose links are as given below. The remote-access to Labs in various disciplines of Science and Engineering is available. Students can conduct experiments which would help them in learning basic and advanced concepts through remote experimentation.

Virtual Lab Website Reference

1. http://vlab.co.in/broad-area-electrical-engineering
2. http://vlab.co.in/broad-area-electronics-and-communications

Term work:

Term work shall consist of minimum 08 experiments. The distribution of marks for term work shall be as follows:

Laboratory Performance	: 10 marks
Journal	: 10 marks
Attendance	: 05 marks

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

Practical and Oral Examination:

Practical will be based on all the laboratory experiments carried out and Oral examination will be based on entire syllabus of **EEC403 - Digital Electronics** and **EEC404 - Power Electronics Devices and Circuits**

The distribution of marks for practical examination shall be as follows:

- Practical Exam : 15 marks
- Oral Exam : 10 marks

Semester-IV								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEL404	**Skill Based Lab- II PCB Design and Fabrication Lab**	-	**04**	**-**	**-**	**02**	**-**	**02**

Examination Scheme								
Theory					Term Work/Practical/Oral			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract./ Oral	Oral	
Test-I	Test-II	Average						
-	-	-	-	-	**50**	-	-	**50**

Course Objectives	**The course is aimed:** 1. To develop the skill set to work on real-life projects and its design. 2. To develop the required skill set to design, develop and assemble the PCB using the CAD tools
Course Outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Understand types of PCBs and various tools used for PCB design. 2. Identify various electrical/electronic components and their packages/ footprints. 3. Illustrate the use of PCB CAD tools and their features for the practical designs. 4. Design the schematic, board layout for simple, moderately complex and complex circuits. 5. Fabricate and assemble the PCBs for simple and moderately complex circuits.

Module	Detailed Contents	Hours
1	**Basics of PCB Designing:** Types of PCBs, Single Layer, Multi-Layer, PCB Materials, PCB designing using different PCB-CAD tools; Schematic Editor, Component libraries with model and footprint, Circuit Emulation, Artwork with auto / manual routing and 3-D Visualization.	**06**
2	**Electrical/ Electronic Components and Packages:** Semiconductor devices and footprints: Diodes: rectifier/ ultrafast/ schottky/ power/ zener diodes, LED, transistors(BJT), SCRs, GTOs, MOSFETs, IGBTs, DIACs, TRIACs etc; Integrated circuits (ICs) and Opto-isolators Different PCB connectors, Terminals, Terminal Blocks; Inductor and Transformers: pulse, low and high frequency); Capacitors and resistors; High voltage devices, Protection elements Component package types: Through Hole Packages: Axial lead, Radial Lead, Single Inline Package(SIP), Dual Inline Package(DIP), Transistor Outline(TO), Through Hole Packages, surface mounted devices (SMD) components.	**06**
3	**PCB Development Tools:** Introduction to open source and commercial softwares like: Proteus, Altium, Eagle, OrCAD, KiCAD etc. Schematic preparation, Selection of Components from standard and special libraries, Components Footprints, net-list, creating new component footprints / library. Updating libraries	**06**

4	**PCB Artwork Designing:** PCB Layout Designing: Placement and layout of components, Design Rule Check (DRC), Electronic rule checking (ERC); PCB Layers: electrical Layers: top Layer, bottom Layer, board outlines and cut-outs, drilling details, components outlines, text; pads, vias, Tracks, colour of layers; Multilayer PCBs. PCB materials: Standard FR-4 Epoxy Glass, Multi-functional FR-4, Tetra Functional FR-4, Polyimide Glass, Teflon etc. Rules for track: PCB conducting layer thickness selection, PCB track width calculation, track length, track angle, track joints, track size; manual routing, auto-routing: Setting up Rules, Defining Constraints; Gerber Generation; PCB Fabrication PCB Making, Printing, Etching, Drilling. EMI and EMC issues in PCB designing.	**10**
5	**PCB Designing in Lab:** **Students should prepare PCBs for at least three projects:** • First project should be a simple circuit: Complete schematic, board layout (single-sided), PCB fabrication, component mounting and testing to be completed. • Second project should be a moderately complex circuit: Complete schematic, board layout (Single layer), PCB fabrication, component mounting and testing to be completed • Third project should be a complex circuit: Complete schematic and board layout (multi-layer) design, gerber files generation to be completed. All three projects are required to be carried out by each individual student (not in a group). For each project a detailed report inclusive of all the schematic, artwork layouts, PCB photos, assembled PCB photos, details of the circuit design and test result etc. must be prepared. Each Project can be carried out based on the following steps: **PCB project:** Selection of circuit, components, components packages, manufacturer (make), generic components, symbols. (i) Selection of circuit: PCB design practice can be carried out for following circuits: 1. Analog Electrical / Electronic Circuits 2. Linear DC Power Supply 3. Op-amp based Signal Processing circuits 4. Different measurement based on transducers /sensors. 5. Mini Project based on Electrical / Electronic domain 6. Microcontroller circuits etc. (ii) Components selection: Students can design/ select the components from datasheets/ manufacturer catalogues / data-book, online supplier's inventory etc. (iii) Selection of PCB type: PCB material, number of layers, thickness of copper etc. (iv) Prepare the schematic and board layout using the open source CAD tools or Licensed CAD tool available in the lab. (v) Fabricate PCB in the lab using printing, etching and drilling process.(Only two projects) (vi) Post PCB fabrication process: component mounting, soldering and Hardware Testing. (vii) Prepare the report on overall lab work carried out with schematics, PCB artwork final PCB fabrication and assembled PCBs photographs.	**24**

Term Work:

Term work shall consist of minimum three PCB designing projects and the reports based on that. The distribution of marks for term work shall be as follows:

Laboratory Performance : 30 marks (PCB design and fabrication- 10 each for three PCBs based on workmanship and quality of work)
Journal : 10 marks
Attendance : 10 marks

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

Books Recommended:

1. Simon Monk, *Make Your Own PCBs with EAGLE: From Schematic Designs to Finished Boards,* 1st Edition, McGraw-Hill Education
2. P. Horowitz and W. Hill*, The Art of Electronics,* 3 Edition, Cambridge University Press.
3. Matthew Scarpino, *Designing Circuit Boards with EAGLE: Make High-Quality PCBs at Low Cost*, 1st Edition Prentice Hall.
4. Archambeault and Drewniak James, *PCB Design for Real-World EMI Control, Springer Publications*

Note: Online demonstrative videos provided by various PCB CAD tools developers can be used to train the students to enable them to gain required skill sets in PCB designing and fabrication essential in engineering career.

Semester-IV								
Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	TW/Pract.	Tut.	Total
EEM401	**Mini Project – 1B**	-	**04$**	**-**	**-**	**02**	**-**	**02**

$ indicates work load of Learner (Not Faculty)

Examination Scheme								
Theory					**Term Work/Practical/Oral**			**Total**
Internal Assessment			End Sem Exam	Duration of End Sem. Exam	Term Work	Pract./ Oral	Oral	
Test-I	Test-II	Average						
-	**-**	**-**	**-**	**-**	**25**	**-**	**25**	**50**

Course Objectives	**The course is aimed:** 1. To acquaint with the process of identifying the needs and converting it into the problem. 2. To familiarize the process of solving the problem in a group. 3. To acquaint with the process of applying basic engineering fundamentals to attempt solutions to the problems. 4. To inculcate the process of self-learning and research.
Course Outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Identify problems based on societal /research needs. 2. Apply Knowledge and skill to solve societal problems in a group. 3. Develop interpersonal skills to work as member of a group or leader. 4. Draw the proper inferences from available results through theoretical/ experimental/simulations. 5. Analyse the impact of solutions in societal and environmental context for sustainable development. 6. Use standard norms of engineering practices 7. Excel in written and oral communication. 8. Demonstrate capabilities of self-learning in a group, which leads to life long learning. 9. Demonstrate project management principles during project work.

(A) General Guidelines for Mini Project 1A/ 1B

- Students shall form a group of 3 to 4 students, while forming a group shall not be allowed less than three or more than four students, as it is a group activity.
- Students should do survey and identify needs, which shall be converted into problem statement for mini project in consultation with faculty supervisor/head of department/internal committee of faculties.
- Students hall submit implementation plan in the form of Gantt/PERT/CPM chart, which will cover weekly activity of mini project.
- A log book to be prepared by each group, wherein group can record weekly work progress, guide/supervisor can verify and record notes/comments.
- Faculty supervisor may give inputs to students during mini project activity; however, focus shall be on self-learning.
- Students in a group shall understand problem effectively, propose multiple solution and select best possible solution in consultation with guide/ supervisor.
- Students shall convert the best solution into working model using various components of their domain areas and demonstrate.
- The solution to be validated with proper justification and report to be compiled in standard format of University of Mumbai.

- With the focus on the self-learning, innovation, addressing societal problems and entrepreneurship quality development within the students through the Mini Projects, it is preferable that a single project of appropriate level and quality to be carried out in two semesters by all the groups of the students. i.e. Mini Project-1 in semester III and IV. Similarly, Mini Project 2 in semesters V and VI.
- However, based on the individual students or group capability, with the mentor's recommendations, if the proposed Mini Project adhering to the qualitative aspects mentioned above gets completed in odd semester, then that group can be allowed to work on the extension of the Mini Project with suitable improvements/modifications or a completely new project idea in even semester. This policy can be adopted on case by case basis.

(B) Mini Project 1A/1B–General Guidelines for Execution

Design and Fabrication

e. Initial fabrication of the project by students can be done using standard devices/material/software tools to verify the circuit functionalities Initial project fabrication and testing is expected to be done by soldering/assembling on general purpose PCB/ Bakelite boards or suitable platforms required for the electrical/electronic/digital components. Avoid the use of breadboards.

f. If essential, use of a simulation/ emulation software tools to test and verify the performance of the circuit should be encouraged.

g. Students should prepare the proper drawings (electrical/ mechanical), schematics/ layouts of the project.

h. For final implementation of the circuit, preparation of PCB (if any required) using suitable CAD tools and fabricating the same in the lab is expected.

Devices/ Components/ Systems to be Used:

Students are encouraged to use passive components like resistors, capacitors, inductors etc. If any specialize inductor is not readily available, the fabrication of the same in the lab should be encouraged. Other components like: Transistors, diodes, voltage regulators, logic gates, Op-amps, general purpose microcontroller, DC motors/ AC motors, sensors, actuators, relays etc. (Students may add more components as per the requirement of project).

Testing and analysis of the Project

Students should test the circuit using suitable laboratory equipments like power supply, multi-meter, CRO, DSO etc. In case of any debugging requirement, students should record the problems faced during the testing and solutions sought after for the fault in the circuit.

All the testing results must be well documented in the final project report verifying the functionalities of the propose project.

Use of Reference Material/Literature :

Students are advised to refer Application Notes, research publications & data sheets of various electrical/electronic/digital devices from Texas Instruments, Microchips, International Rectifiers, ST Microelectronics, Philips, NXP and many other manufacturers.

(C) Self-learning and Skill Set Development

Students should be encouraged to develop/ improve their understanding and skill sets by attending various online/offline expert lectures / video lectures/ courses/ webinars/ workshops etc. to facilitate the smooth execution of mini project

1. Understanding passive components viz. resistors, capacitors and inductors from practical point of view: types/ varieties, device packages, applications and cost.
2. Understanding semiconductor components viz. diodes, BJT and JFET/MOSFETs from practical point of view: types/ varieties, device packages, applications and cost.
3. Design principles of simple electrical / electronic circuits with some examples.
4. Selection of switches and circuit protection components.
5. Selection and sizing of wires and conductors.
6. Soldering Practice.
7. Heat-sinking and Enclosure design concepts
8. Overall workmanship while working on the project fabrication.
9. Use of different software tools for design and development of circuits

10. Use of standard as well as advanced laboratory equipments needed for testing of such projects

(D) Suggested List of Application Domains/ Software tools/ Online Repository for Mini Projects

List of key application domains from where students are encouraged to derive Mini Projects topics:

1. Home/Office automation
2. Renewable Energy
3. Energy Conservation
4. Energy Storage
5. Battery Charging and Protection
6. Fire Safety
7. Electrical System Protection
8. Lighting Control
9. Wireless Power Transfer
10. Electrical Components Testing
11. Electrical Parameters Measurement
12. Non-conventional Electricity Generation
13. Laboratory Equipments
14. E-Mobility
15. Video Surveillance Systems
16. Robotics for Hazardous applications
17. Waste Management System 2.
18. Smart City Solutions
19. Smart Classrooms and learning Solutions
20. Smart Agriculture solutions etc.
21. Health/ Biomedical

Students can identify the mini project topics either from above suggested domains or **any other relevant engineering domains**.

Reference Books:

1. P. Horowitz and W. Hill, "The Art of Electronics", 3rd Edition, Cambridge University Press, 2015
2. R. S. Khandpur, "Printed Circuit Board", McGraw-Hill Education; 1st edition, 2005.
3. Simon Monk, "Hacking Electronic: Learning Arduino and Raspberry Pi", McGraw-Hill Education TAB; 2 edition (September 28, 2017).

Suggested Software Tools:

1. LTspice:https://www.analog.com/en/design-center/design-tools-and-calculators/ltspice-simulator.html#
2. Eagle : https://www.autodesk.in/products/eagle/overview
3. OrCAD: https://www.orcad.com/
4. Multisim : https://www.multisim.com/
5. Webbench:http://www.ti.com/design-resources/design-tools-simulation/webench-power-designer.html
6. Tinkercad : https://www.tinkercad.com/
7. Raspbian OS: https://www.raspberrypi.org/downloads
8. Arduino IDE: https://www.arduino.cc/en/main/software

Online Repository:

1. https://www.electronicsforu.com
2. https://circuitdigest.com
3. https://www.electronicshub.org
4. Github

(E) Guidelines for Assessment of Mini Project

Term Work

- The review/ progress monitoring committee shall be constituted by head of departments of each institute. The progress of mini project to be evaluated on continuous basis, minimum two reviews in each semester.
- In continuous assessment focus shall also be on each individual student, assessment based on individual's contribution in group activity, their understanding and response to questions.
- Distribution of Term work marks for both semesters shall be as below;
  - Marks awarded by guide/supervisor based on log book : 10
  - Marks awarded by review committee : 10
  - Quality of Project report : 05

Review/progress monitoring committee may consider following points for assessment based on either one year or half year project as mentioned in general guidelines.

<u>One-year Mini Project:</u>

- In first semester entire theoretical solution shall be ready, including components/system selection and cost analysis. Two reviews will be conducted based on presentation given by students group.
  - First shall be for finalization of problem
  - Second shall be on finalization of proposed solution of problem.
- In second semester expected work shall be procurement of components /systems, building of working prototype, testing and validation of results based on work completed in an earlier semester.
  - First review is based on readiness of building working prototype to be conducted.
  - Second review shall be based on poster presentation cum demonstration of working model in last month of the said semester.

<u>Half-year Mini Project:</u>

- In this case in one semester students' group shall complete project in all aspects including,
  - Identification of need/problem
  - Proposed final solution
  - Procurement of components/systems
  - Building prototype and testing
- Two reviews will be conducted for continuous assessment,
  - First shall be for finalization of problem and proposed solution
  - Second shall be for implementation and testing of solution.

(F) Assessment criteria of Mini Project

Mini Project shall be assessed based on following criteria;

1. Quality of survey/ need identification
2. Clarity of Problem definition based on need.
3. Innovativeness in solutions
4. Feasibility of proposed problem solutions and selection of best solution
5. Cost effectiveness
6. Societal impact
7. Innovativeness
8. Cost effectiveness and Societal impact
9. Full functioning of working model as per stated requirements
10. Effective use of skill sets
11. Effective use of standard engineering norms
12. Contribution of an individual's as member or leader
13. Clarity in written and oral communication

- In **one year, project**, first semester evaluation may be based on first six criteria's and remaining may be used for second semester evaluation of performance of students in mini project.

- In case of **half year project** all criteria's in generic may be considered for evaluation of performance of students in mini project.

Guidelines for Assessment of Mini Project Practical/Oral Examination:

- Report should be prepared as per the guidelines issued by the University of Mumbai.
- Mini Project shall be assessed through a presentation and demonstration of working model by the student project group to a panel of Internal and External Examiners preferably from industry or research organizations having experience of more than five years approved by head of Institution.
- Students shall be motivated to publish a paper based on the work in Conferences/students competitions.

Oral Examination:

Mini Project shall be assessed based on following points;

1. Quality of problem and Clarity
2. Innovativeness in solutions
3. Cost effectiveness and Societal impact
4. Full functioning of working model as per stated requirements
5. Effective use of skill sets
6. Effective use of standard engineering norms
7. Contribution of an individual's as member or leader
8. Clarity in written and oral communication

****

AC- 29/6/2021
Item No.- 6.4

UNIVERSITY OF MUMBAI

Bachelor of Engineering

in

Electrical Engineering

Third Year with Effect from AY 2021-22

(REV- 2019 'C' Scheme) from Academic Year 2019 – 20

Under

FACULTY OF SCIENCE & TECHNOLOGY

(As per AICTE guidelines with effect from the academic year 2019–2020)

AC: 29/6/2021
Item No.-6.4

UNIVERSITY OF MUMBAI

Syllabus for Approval

Sr. No.	Heading	Particulars
1	Title of the Course	**Third Year in Bachelor of Electrical Engineering**
2	Eligibility for Admission	**After Passing Second Year Engineering as per the Ordinance 0.6243**
3	Passing Marks	**40%**
4	Ordinances / Regulations (if any)	**Ordinance 0.6243**
5	No. of Years / Semesters	**8 semesters**
6	Level	**Under Graduation**
7	Pattern	**Semester**
8	Status	**Revised**
9	To be implemented from Academic Year	**With effect from Academic Year: 2021-2022**

Date:29/6/2021

Dr. S. K. Ukarande
Associate Dean, Faculty of Science and Technology
University of Mumbai

Dr Anuradha Muzumdar
Dean, Faculty of Science and Technology
University of Mumbai

Preamble

To meet the challenge of ensuring excellence in engineering education, the issue of quality needs to be addressed, debated and taken forward in a systematic manner. Accreditation is the principal means of quality assurance in higher education. The major emphasis of accreditation process is to measure the outcomes of the program that is being accredited. In line with this Faculty of Science and Technology (in particular Engineering) of University of Mumbai has taken a lead in incorporating philosophy of outcome based education in the process of curriculum development.

Faculty resolved that course objectives and course outcomes are to be clearly defined for each course, so that all faculty members in affiliated institutes understand the depth and approach of course to be taught, which will enhance learner's learning process. Choice based Credit and grading system enables a much-required shift in focus from teacher-centric to learner-centric education since the workload estimated is based on the investment of time in learning and not in teaching. It also focuses on continuous evaluation which will enhance the quality of education. Credit assignment for courses is based on 15 weeks teaching learning process, however content of courses is to be taught in 13 weeks and remaining 2 weeks to be utilized for revision, guest lectures, coverage of content beyond syllabus etc.

There was a concern that the earlier revised curriculum more focused on providing information and knowledge across various domains of the said program, which led to heavily loading of students in terms of direct contact hours. In this regard, faculty of science and technology resolved that to minimize the burden of contact hours, total credits of entire program will be of 170, wherein focus is not only on providing knowledge but also on building skills, attitude and self learning. Therefore in the present curriculum skill based laboratories and mini projects are made mandatory across all disciplines of engineering in second and third year of programs, which will definitely facilitate self learning of students. The overall credits and approach of curriculum proposed in the present revision is in line with AICTE model curriculum.

The present curriculum will be implemented for Third Year of Engineering from the academic year 2021-22. Subsequently this will be carried forward for Final Year Engineering in the academic year 2022-23.

Dr. S. K. Ukarande
Associate Dean
Faculty of Science and Technology
University of Mumbai

Dr Anuradha Muzumdar
Dean
Faculty of Science and Technology
University of Mumbai

Incorporation and Implementation of Online Contents from NPTEL/ Swayam Platform

The curriculum revision is mainly focused on knowledge component, skill based activities and project based activities. Self learning opportunities are provided to learners. In the revision process this time in particular Revised syllabus of 'C ' scheme wherever possible additional resource links of platforms such as NPTEL, Swayam are appropriately provided. In an earlier revision of curriculum in the year 2012 and 2016 in Revised scheme 'A' and 'B' respectively, efforts were made to use online contents more appropriately as additional learning materials to enhance learning of students.

In the current revision based on the recommendation of AICTE model curriculum overall credits are reduced to 171, to provide opportunity of self learning to learner. Learners are now getting sufficient time for self learning either through online courses or additional projects for enhancing their knowledge and skill sets.

The Principals/ HoD's/ Faculties of all the institute are required to motivate and encourage learners to use additional online resources available on platforms such as NPTEL/ Swayam. Learners can be advised to take up online courses, on successful completion they are required to submit certification for the same. This will definitely help learners to facilitate their enhanced learning based on their interest.

Dr. S. K. Ukarande
Associate Dean
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University of Mumbai

Dr Anuradha Muzumdar
Dean
Faculty of Science and Technology
University of Mumbai

Preface By BoS

The outcome based course curriculum for the undergraduate degree in Electrical Engineering in Rev.2019 ‘C’ scheme has been chalked out through the thoughtful discussions and deliberations of academic and industry experts. While devising the syllabus content framework, the correct balance between the fundamental / core topics with appropriate mix of topics from the state of the art technologies in electrical and allied domains is attempted. With the increased Industry-Institute interaction and internship programs, students are encouraged to explore the opportunity to improve communication skills, problem solving skill and good team management. These skills shall surely help them to meet the future challenges in their career.

The new course curriculum will also give ample opportunity to the students to work in cross discipline domains to gain the hands on experience through the project based learning facilitated through the various skill based labs, Mini projects, Course projects , Major projects etc. The increased number of department and institute level electives shall facilitate students with the truly choice based learning and skilling in a particular domains.

On behalf of the Board of Studies (BoS) in Electrical Engineering of the University of Mumbai, we seek the active participation from all the stake holders of the engineering education to meet the set outcomes and objectives for the Undergraduate Program in Electrical Engineering.

Board of Studies in Electrical Engineering

Dr. Sushil S. Thale	**: Chairman**
Dr. B. R. Patil	**: Member**
Dr. S. R. Deore	**: Member**
Dr. B. B. Pimple	**: Member**
Dr. Nandkishor Kinhekar	**: Member**

Program Structure for Third Year Electrical Engineering
(Semester V & VI)
University Of Mumbai
(With Effect from 2021-2022)
Semester V

Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Pract.	Theory	Pract.	Total
EEC501	Electrical AC Machines II	3	--	3	--	3
EEC502	Electrical Power System II	3	--	3		3
EEC503	Control System	3	--	3	--	3
EEC504	Electromagnetic Field and Wave	3	--	3	--	3
EEDO501X	Department Optional Course – 1	3	--	3	--	3
EEL501	Electrical AC Machines Lab II	--	2	--	1	1
EEL502	Simulation Lab II	--	2	--	1	1
EEL503	Control System Lab	--	2	--	1	1
EEL504	Professional Communication and Ethics-II	--	2*+2	--	2	2
EEM501	Mini Project – 2 A	--	4$	--	2	2
Total		**15**	**14**	**15**	**07**	**22**

Course Code	Course Name	Examination Scheme							
		Theory					Term Work	Prac / Oral	Total
		Internal Assessment			End Sem Exam	Exam. Duration (in Hrs)			
		Test1	Test2	Avg					
EEC501	Electrical AC Machines-II	20	20	20	80	3	--	--	100
EEC502	Electrical Power System-II	20	20	20	80	3	--	--	100
EEC503	Control System	20	20	20	80	3	--	--	100
EEC504	Electromagnetic Field and Wave	20	20	20	80	3	--	--	100
EEDO501X	Department Optional Course – 1	20	20	20	80	3	--	--	100
EEL501	Electrical AC Machines Lab-II	--	--	--	--	--	25	25	50
EEL502	Simulation Lab-II	--	--	--	--	--	25	25	50
EEL503	Control System Lab	--	--	--	--	--	25	25	50
EEL504	Professional Communication and Ethics-II	--	--	--	--	--	25	25	50
EEM501	Mini Project – 2A	--	--	--	--	--	25	25	50
Total		**--**	**--**	**100**	**400**	**--**	**125**	**125**	**750**

* Theory class to be conducted for full class
$ indicates work load of Learner (Not Faculty), for Mini Project; **Faculty Load**: 1 hour per week per four groups

Semester VI

Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Pract./ Tut.	Theory	Pract.	Total
EEC601	Power System Protection & Switchgear	3	--	3	--	3
EEC602	Microcontroller Applications	3	--	3		3
EEC603	Control System Design	3	--	3	--	3
EEC604	Signals and Systems	3	--	3	--	3
EEDO601X	Department Optional Course – 2	3	--	3	--	3
EEL601	Power System Protection & Switchgear Lab	--	2	--	1	1
EEL602	Microcontroller Applications Lab	--	2	--	1	1
EEL603	Control System Design Lab	--	2	--	1	1
EEL604	SBL-III: Industrial Automation Lab	--	4	--	2	2
EEM601	Mini Project – 2 B	--	4[$]	--	2	2
Total		**15**	**14**	**15**	**07**	**22**

Course Code	Course Name	Examination Scheme							
		Theory					Term Work	Prac / Oral	Total
		Internal Assessment			End Sem Exam	Exam. Duration (in Hrs)			
		Test1	Test2	Avg					
EEC601	Power System Protection & Switchgear	20	20	20	80	3	--	--	100
EEC602	Microcontroller Applications	20	20	20	80	3	--	--	100
EEC603	Control System Design	20	20	20	80	3	--	--	100
EEC604	Signals and Systems	20	20	20	80	3	--	--	100
EEDO601X	Department Optional Course – 2	20	20	20	80	3	--	--	100
EEL601	Power System Protection & Switchgear Lab	--	--	--	--	--	25	25	50
EEL602	Microcontroller Applications Lab	--	--	--	--	--	25	25	50
EEL603	Control System Design Lab	--	--	--	--	--	25	--	25
EEL604	SBL-III: Industrial Automation Lab	--	--	--	--	--	25	25	50
EEM601	Mini Project – 2 B	--	--	--	--	--	25	25	50
Total		**--**	**--**	**100**	**400**	**--**	**125**	**100**	**725**

$ indicates work load of Learner (Not Faculty), for Mini Project; **Faculty Load**: 1 hour per week per four groups

Department Optional Courses

Sem. V: Department Optional Course – 1 EEDO5011: Renewable Energy Sources EEDO5012: Advanced Power Electronics EEDO5013: Advanced Measurements and Instrumentation EEDO5014: Analog and Digital Communication
Sem. VI: Department Optional Course – 2 EEDO6011: Special Electrical Machine EEDO6012: Electric Traction EEDO6013: High Voltage Engineering EEDO6014: Energy Storage

ELECTRICAL ENGINEERING - SEMESTER-V						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits assigned		
EEC501	Electrical AC Machines -II	Theory	Pract./Tut.	Theory	Pract /Tut.	Total
		3	--	3	--	3

Course Code	Course Name	Examination Scheme							
		Theory					Term work	Pract./ Oral	Total
		Internal Assessment			End Sem. Exam.	Exam. Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEC501	Electrical AC Machines -II	20	20	20	80	03	-	-	100

Course Objectives	• To impart knowledge of operation and performance of synchronous machine
Course Outcomes	Upon successful completion of this course, the learner will be able: 1. To illustrate the working of synchronous generator 2. To determine the voltage regulation of synchronous generator by different methods 3. To analyze the parallel operation of synchronous generators. 4. To apply Blondel's two reaction theory and solve simple problems on salient pole synchronous machines. 5. To analyze the operation of synchronous motor. 6. To derive the basic machine relations in dq0 variables for a synchronous machine without considering damper winding.

Module	Contents	Hours
1	Synchronous Generator-Introduction: Construction, Operation, E.M.F. equation, Winding factors, Armature reaction	03
2	Analysis of Synchronous Generator: Phasor diagrams of cylindrical rotor synchronous generator, Voltage regulation, No load (OC) and SC test, Voltage regulation methods: EMF, MMF, ZPF, ASA.	06
3	Performance of Synchronous Generator: Power flow equations and maximum power conditions, Need for parallel operation and conditions, Effect of variation of field current and prime mover input on parallel operation, Concept of infinite bus, Effect of variation of field current on alternator connected to infinite bus, Numerical problems on parallel operation.	10
4	Salient pole synchronous generator: Concept of direct and quadrature reactance, Blondel's two reaction theory, Phasor diagram of salient pole machine, Power angle characteristics, Synchronizing power and torque.	06
5	Synchronous Motor: Principle of operation, Self-starting methods, Phasor diagram, Load angle (δ), Power flow equations and maximum power conditions, Effect of change in excitation and mechanical power on performance of motor, V and Inverted V curves, Power factor control, Hunting, Excitation and power circles, Measurement of X_d and X_q by slip test, Starting against high torques.	09
6	Theory of Synchronous Machines: Ideal synchronous machine, Transformation to direct and quadrature axis variables, basic machine relations in dq0 variables (Primitive model of synchronous machine without considering damper winding), steady state analysis.	05

Text Books:

1. Bimbhra P.S., Electric Machinery, Khanna Publisher
2. Bimbhra P.S., Generalized Machine Theory, Khanna Publisher
3. V. K. Mehta, Principles of Electrical Machines, S Chand Publication

Reference Books:

1. M.G. Say, Performance and Design of Alternating Current Machines, CBS Pub.
2. Ashfaq Husain, Electric Machines, Dhanpat Rai and co. publications
3. A.E. Fitzgerald, Kingsly, Stephen, Electric Machinery, Tata McGraw Hill

Web Reference /Video Courses

1. NPTEL Course: Electrical Machines-II By Prof. Krishna Vasudevan, Prof. G. Sridhara Rao, Prof. P. Sasidhara Rao, IIT-Madras. Weblink- https://nptel.ac.in/courses/108/106/108106072/
2. NPTEL Course: Electrical Machines By Prof. G. Bhuvaneshwari, Dept. of Electrical Engineering , IIT-Delhi. Weblink:- https://nptel.ac.in/courses/108/102/108102146/
3. NPTEL Course: Electrical Machines-II By Prof. Tapas Kumar Bhattacharya, Dept. of Electrical Engg. ,IIT-Kharagpur. Weblink:- https://nptel.ac.in/courses/108/105/108105131/

Assessment:

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

Theory Examination:

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

ELECTRICAL ENGINEERING - SEMESTER-V						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits assigned		
EEC502	**Electrical Power System II**	**Theory**	**Pract./Tut.**	**Theory**	**Pract /Tut.**	**Total**
		3	**--**	**3**	**--**	**3**

Course Code	Course Name	Examination Scheme							
		Theory					Term work	Pract./ Oral	Total
		Internal Assessment			End Sem. Exam.	Exam. Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEC502	**Electrical Power System II**	**20**	**20**	**20**	**80**	**03**	**--**	**-**	**100**

Course Objectives	1. To understand different types of faults and their analysis. 2. To understand power system transients and insulation coordination. 3. To understand concept of corona.
Course outcomes	**Upon successful completion of this course, the learner will be able to** 1. Understand and analyse unsymmetrical faults on transmission line 2. Analyse symmetrical component and construct sequence network 3. Analyse symmetrical faults on transmission lines. 4. Understand power system transients 5. Understand phenomenon of lightning and insulation coordination. 6. Understand concept of corona.

Module	Contents	Hours
1.	**Symmetrical Fault Analysis:** Introduction to synchronous machine, basic construction, operation and equivalent circuit diagram, short circuit of synchronous machine: no load and loaded machine, transient on a transmission line, selection of Circuit breaker, short circuit MVA. Algorithm for SC studies, Z Bus formulation, symmetrical fault analysis using Z bus. **(Numerical)**	10
2.	**Symmetrical Components:** Introduction, Symmetrical component transformation, phase shift in star-delta transformers, sequence impedances and sequence network of transmission line, synchronous machine and transformer, power invariance, construction of sequence network of a power system. **(Numerical)**	08
3.	**Unsymmetrical Fault Analysis:** Types of unsymmetrical faults, Analysis of shunt type unsymmetrical faults: single line to ground (SLG) fault, line to line (L-L) fault, double line to ground (LLG) fault. **(Numerical)**	05
4.	**Power System Transients:** Review of transients in simple circuits, recovery transient due to removal of short circuit, arcing grounds, capacitance switching, current chopping phenomenon. Travelling waves on transmission lines, wave equation, reflection and refraction of waves, typical cases of line terminations, attenuation, Bewely lattice diagram. **(Numerical)**	06
5.	**Lightning and Insulation Coordination:** Lightning phenomenon, mechanism of Lightning stroke, shape of Lightning voltage wave, over voltages due to Lightning, Lightning protection problem, significance of tower footing resistance in relation to Lightning, insulator flashover and withstand voltages, protection against surges, surge arresters, surge capacitor, surge reactor and surge absorber, Lightning arrestors and protective characteristics, dynamic voltage rise and arrester rating.	06

	Insulation Coordination:- Volt time curve, basic approach to insulation co-ordination in power system, over voltage protection, ground wires, insulation coordination based on lightning, surge protection of rotating machines and transformers.	
6.	**Corona:** Phenomenon of corona, Disruptive critical voltage, Visual critical voltage, corona loss, factors affecting corona loss, Radio interference due to corona, practical considerations of corona loss, corona in bundled conductor lines, corona ring. **(Numerical)**	04

Text Books:-

1. B.R. Gupta, Power System Analysis and Design, S. Chand, 4e
2. D. P. Kothari, I. J. Nagrath, "Power System Engineering", 3e, Mc Graw Hill
3. Wadhwa C.L. Electrical power system, New Age International, 4e
4. Mehta V.K., Principles of Power System, S. Chand

Reference Books:-

1. Hadi Saadat, Power System Analysis, TMH publications
2. Turan Gonen, Modern power system analysis, Wiley
3. Stevenson and Grainger, Modern power system analysis, TMH publication, 1ed

Website Reference/ Video Courses:

1. NPTEL Course: **Power Systems Analysis** By Prof. Arindam Ghosh, Department of Electrical Engineering IIT Kanpur :-Web link- https://nptel.ac.in/courses/108/106/108106098/

Assessment:

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

Theory Examination:

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

ELECTRICAL ENGINEERING - SEMESTER-V						
Course Code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEC503	Control Systems	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		3	--	3		3

Course Code	Course Name	Examination Scheme							
		Theory					Term Work	Pract/ Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEC503	Control Systems	20	20	20	80	3	-	-	100

Course Objectives	1. Modeling of electric, mechanical and electromechanical systems, using differential equations, transfer functions, block diagrams, and state variables. 2. To analyze and design system parameters to meet transient and steady state error performance specifications. 3. To learn time response analysis and demonstrate their knowledge to frequency response 4. To learn stability analysis of system using Root locus, bode plot, polar plot, and Nyquist plot.
Course outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Demonstrate an understanding of the fundamentals of (feedback) control systems. 2. Determine and use models of physical systems in forms suitable for use in the analysis and design of control systems. 3. Express and solve system equations in state-variable form (state variable models). 4. Determine the time and frequency-domain responses of first and second-order systems to step and sinusoidal (and to some extent, ramp) inputs. 5. Determine the (absolute) stability of a closed-loop control system

Module	Contents	Hours
1.	Introduction to Control System: Elements of control systems, concept of open loop and closed loop systems, Examples and application of open loop and closed loop systems. Concept of feedback and Automatic control, Effects of feedback	03
2.	Mathematical Model of Physical System Transfer function of electrical, mechanical (translational and rotational) System. Force Voltage and Force Current analogies. Transfer function model of AC & DC servomotor, potentiometer & tacho-generator. Block diagram reduction technique and signal flow graph, Mason's rule, Signal flow graph of electrical network. Conversion of BDR to SFG and vice versa.	08
3.	Time Domain Analysis: Time domain analysis of a standard second order closed loop system. Concept of un-damped natural frequency, damping, overshoot, rise time and settling time. Dependence of time domain performance parameters on natural frequency and damping ratio. Step and Impulse response of first and second order systems. Effects of Pole and Zeros on transient response. Stability by pole location. Routh-Hurwitz criteria and applications. Error Analysis: Steady state errors in control systems due to step, ramp and parabolic inputs. Concepts of system types and error constants.	09
4.	State Variable Analysis Introduction to state variable, General state space representation, State space representation of Electrical and Mechanical systems. Conversion between state space and transfer function. Alternative representations in state space: (Phase variable, canonical, parallel & cascade). Similarity transformations, diagonalizing a system matrix. Laplace Transform solution of state equation, stability in state space	07

5.	Root locus Techniques: Definition and properties of root locus, rules for plotting root locus, stability analysis using root locus.	04
6.	Frequency Domain Analysis: Polar plots, Bode plot, stability in frequency domain, Nyquist plots. Nyquist stability criterion. Gain margin and phase margin via Nyquist diagram and Bode plots.	08

Text Books:-

1. Control System Engineering by Norman Nise
2. Control System Engineering by Nagrath and Gopal, 5th to latest edition , Wiley Eastern
3. Modern Control System Engineering by K. Ogata, Prentice Hall
4. Modern Control Systems, Twelfth edition, by Richard C Dorf, Robert H Bishop, Pearson.
5. Gopal, M., Digital Control System, Wiley Eastern (1986).

Reference Books:-

1. Linear Control system Analysis and design with MATLAB, by J.J. Azzo, C. H. Houpis S.N. Sheldon, Marcel Dekkar
2. Feedback control of Dynamic System, G.F. Franklin, Pearson higher education,
3. Control System Engineering, Shivanagraju s. Devi L., New Age International
4. Control Systems Technology, Curtis Johnson, Heidar Malki, Pearson
5. Control Systems Engineering, S. K. Bhattacharya, Pearson.
6. Control Systems, Theory and applications, Smarajit Ghosh, Pearson

Web Reference /Video Courses

1. NPTEL Course: Control Engineering By Prof. Ramkrishna Pasumarthy, Department of Electrical Engineering, IIT Madras :-Web link- https://nptel.ac.in/courses/108/106/108106098/
2. NPTEL Course: Control Systems By Prof. C.S. Shankar Ram, Department of Design Engineering, IIT Madras :-Web link- https://nptel.ac.in/courses/107/106/107106081/
3. NPTEL Course: Control Engineering By Prof. S.D. Agashe, Department of Electrical Engineering, IIT Bombay :-Web link- https://nptel.ac.in/courses/108/101/108101037/

Assessment:

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

Theory Examination:

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

ELECTRICAL ENGINEERING - SEMESTER-V						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
EEC504	Electromagnetic Field and Wave	Theory	Pract./Tut.	Theory	Pract /Tut.	Total
		3	--	3	--	3

Course Code	Course Name	Examination Scheme							
		Theory					Term work	Pract./ Oral	Total
		Internal Assessment			End Sem. Exam.	Exam. Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEC504	Electromagnetic Field and Wave	20	20	20	80	03	--	-	100

Course Objectives	1. Implement the knowledge of mathematics and physics. 2. Visualize Electric field. 3. Visualize magnetic field 4. Understand their application in electrical engineering 5. Analyse time varying electric and magnetic fields 6. Formulate electromagnetic wave equation
Course outcomes	Upon successful completion of this course, the learner will be able to: 1. Apply knowledge of mathematics and physics in electrical engineering field. 2. Analyze electrostatic fields 3. Apply and analyse magneto-static fields. 4. Analyze the effect of material medium on electric and magnetic fields. 5. Analyze and formulate time varying electric and magnetic fields. 6. Formulate wave equations for Electromagnetic wave propagation in different media.

Module	Contents	Hours
1.	Vector Basics: Introduction to Vectors Calculus, Rectangular, Cylindrical and Spherical Co-ordinate System, Co-ordinate and vector transformation; Numericals on line, Surface and Volume Integrals.	05
2.	Static Electric Fields: Coulomb's Law in Vector Form, Electric Field Intensity, Definition, Principle of Superposition, Electric Field due to point charges, Electric Field due to line charge (one and two conductor transmission lines), Electric Field due to an infinite uniformly charged sheet, Definition and physical interpretation of gradient, Electric scalar potential, Relationship between potential and electric field and its application on Surface voltage gradient on conductor. Numericals	12
3.	Static Magnetic Fields: The Biot-Savart's Law in vector form, Magnetic Field intensity due to a finite and infinite wire carrying a current I, Magnetic field intensity on the axis of a circular loop carrying a current I, Ampere's circuital law and its application on A solid cylindrical conductor and Infinitely long coaxial transmission line, Magnetic flux density, Definition and physical Interpretation of Curl, The Lorentz force equation for a moving charge and its applications on Force on a wire carrying a current I placed in a magnetic field, Magnetic Vector Potential. Numericals	08
4.	Electric and Magnetic Fields in Materials: Poisson's and Laplace's equation , Electric Polarization, Electric current, Current density, Point form of ohm's law, Continuity equation for current Numericals	06

5.	Time varying Electric and Magnetic Fields: Faraday's law, Maxwell's Second Equation in integral form from Faraday's Law, Equation expressed in point form, Displacement current, Ampere's circuital law in integral form, Modified form of Ampere's circuital law as Maxwell's first equation in integral form, Equation expressed in point form, Maxwell's four equations in integral form and differential form. Numericals	05
6.	Electromagnetic Wave theory: Derivation of Wave Equation, Uniform Plane Waves, Maxwell‟s equation in phasor form, Wave equation in phasor form. (No numericals)	03

Self Study Topics- Potential due to electrical dipole and flux lines, Electric Flux Density, Gauss Law Definition and physical Significance of Divergence, Divergence theorem. Application on Estimation and control of electric stress, control of stress at an electrode edge.

Note: Students should be encouraged to study the self-study topics through text books, reference books , online courses /contents etc. The students' performance on self-study contents be verified through MCQs and/or presentations or any other suitable methodology.

Text/Reference Books:-

1. W. Hayt, "Engineering electromagnetic", McGraw Hill, 4th edition, 1987.
2. Edminister, "Schaum‟s series in electromagnetic" McGraw Hill publications, 3rd edition, 1986.
3. M.N.O.Sadiku, "Elements of Engineering Electromagnetics" Oxford University Press, 3rd Ed.
4. N. Narayan Rao, "Elements of Electromagnetic", PHI publication, 4th edition, 2001.
5. David K.Cherp, "Field and Wave Electromagnetics - Second Edition-Pearson Edition

Website Reference/ Video Courses:

1. NPTEL Course: **Electromagnetic Fields** By Prof. Harishankar Ramachandran, Department of Electrical Engineering IIT Madras :-Web link- https://nptel.ac.in/courses/108/106/108106098/

Assessment:

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

Theory Examination:

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

ELECTRICAL ENGINEERING - SEMESTER-V						
Course Code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEDO5011	**Renewable Energy Sources**	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		3	--	3		3

Course Code	Course Name	Examination Scheme							
		Theory					Term Work	Pract/ Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEDO5011	**Renewable Energy Sources**	20	20	20	80	3	-	-	100

Course Objectives	1. To review of conventional and non-conventional energy sources. 2. To give the students basic knowledge of solar thermal energy applications 3. To give the students basic knowledge solar photovoltaic system 4. To give the students basic knowledge of wind energy system 5. To give the students basic knowledge of fuel cell system operation 6. To give the students basic knowledge about other renewable energy sources.
Course outcomes	Upon successful completion of this course, the learner will be able to: 1. Understand different types conventional energy sources and their reserves 2. Identify and analyse the process of power generation through solar thermal energy utilization 3. Identify and analyse the process of power generation through solar photovoltaic energy utilization 4. Identify and describe the various components and types of Wind Energy system 5. Identify and describe the basic operation and types of Fuel cell system 6. Understand different types of other non-conventional energy sources

Module	Contents	Hours
1.	Introduction-: World's and India's production and reserves of commercial energy sources, energy alternatives, review of conventional and non-conventional energy sources. Statistic of net potential and current generation status of different energy alternatives.	04
2.	Solar Energy (Thermal Energy applications) : Solar thermal energy storage, Liquid flat plate collector, Solar air heater, concentrating collectors, thermal energy storage, solar pond	04
3.	Solar Energy (Direct Electricity Applications): Solar Photovoltaic- solar cell: characteristics, losses, model of a solar cell, emerging solar cell technologies; Solar PV modules, mismatch in module, hot spots, bypass diode; PV module: I-V and power curve, effect of variation in temperature and solar radiations; MPPT, types, different algorithms for electrical MPPT. Distributed MPPT, MPPT converters. Types of PV systems: standalone, grid connected systems; BOS of PV system, Battery charge controllers, Power Conditioning Unit, Solar PV Micro-inverters Solar Plant design: mounting of PV panels supporting structures, Calculation and Design methodology of standalone PV system and grid connected system.	12
4.	Wind Energy: Review of wind energy system and its components, types of wind turbines, characteristics; general concepts of aerofoils and aerodynamics, Wind data, Energy content of the wind, Power generation and control in wind energy systems, performance calculations of wind energy systems. Topologies of WES, WES with rectifier / inverter system, Power Converters for Doubly Fed Induction Generators (DFIG) in Wind Turbines.	08

5.	**Fuel Cell:** Review of fuel cells and their principle of operation, Review of types of fuel cell and their performance comparison. Topologies of fuel cell power systems, applications.	05
6.	**Other Sources:** Review of other nonconventional sources, their features and applications; Biomass, Tidal, Ocean, Thermal Electric Conversion, geothermal, Micro-hydro, Wave energy	06

Text / Reference Books:

1. Ali Keyhani, Mohammad N. Marwali, Min Dai "Integration of Green and Renewable Energy in Electric Power Systems", Wiley
2. Green M.A " Solar Cells": Operating Principles, Technology and System Applications, Prentice Hall Inc, Englewood Cliffs N.J, U.S.A, 1982
3. James Larminie, Andrew Dicles "Fuel Cell Systems Explained," Wiley publication
4. Chetan Singh Solanki , Solar Photo Voltaics , PHI Learning Pvt Ltd., New Delhi,2009
5. Hashem Nehrir and Caisheng Wang, Modeling and control of Fuel Cells: Distributed Generation Applications, IEEE Press, 2009
6. J.F. Manwell and J.G. McGowan, Wind Energy Explained, Theory Design and Applications, Wiley publication
7. Leo J.M.J. Blomen and Michael N. Mugerwa, "Fuel Cell System", New York, Plenum Press, 1993.
8. D. D. Hall and R. P. Grover, Biomass Regenerable Energy, John Wiley, New York, 1987.
9. Felix A. Farret and M. Godoy Simoes, Integration of Alternative Sources of Energy, 2006, John Wiley and Sons.
10. S. Chakraborty, M. G. Simões and W. E. Kramer, Power Electronics for Renewable and Distributed Energy System, Springer 2013
11. N. Femia • G. Petrone, G. Spagnuolo and M. Vitelli, Power Electronics and Control Techniques for Maximum Energy Harvesting in Photovoltaic Systems, CRC Press, 2013.

Website Reference/ Video Courses:

1. **NPTEL Course: Energy Resources & Technology** By Prof. S. Banerjee, IIT Kharagpur:- Web link- https://nptel.ac.in/courses/108/105/108105058/
2. **NPTEL Course: Non-Conventional Energy Systems** By Prof. L. Umanand, IISC Bangalore:- Web link- https://nptel.ac.in/courses/108/108/108108078/

Assessment:

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

Theory Examination:

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

ELECTRICAL ENGINEERING - SEMESTER-V						
Course Code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEDO5012	Advanced Power Electronics	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		3	--	3		3

Course Code	Course Name	Examination Scheme							
		Theory					Term Work	Pract/ Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEDO5012	Advanced Power Electronics	20	20	20	80	3	-	-	100

Course Objectives	1. To understand and analyse dc to dc conversion with isolation and hence to analyze different converter circuits for power conversion. 2. To understand the principles of design of magnetics such as high frequency transformers and inductors. 3. To keep abreast with the latest technologies and research going on in different areas related to power electronics. 4. To enhance the capability of problem solving skills. 5. To model the converter and design the controller for deeper understanding and detailed analysis.
Course outcomes	Upon successful completion of this course, the learner will be able to: 1. Analyze and select dc to dc power electronic converter topology for energy conversion applications. 2. Apply the basic concepts of magnetics to design high frequency transformers and Inductors for dc to dc converter topologies. 3. Analyze resonant power electronic converter topologies for high frequency applications 4. Model and design controllers for the closed loop operation of dc to dc converters. 5. Apply the basic concepts of power electronics in the fields of AC and DC drives, power generation and energy conversion, industrial applications, extraction of energy from renewable sources.

Module	Contents	Hours
1.	**Switching Voltage Regulators:** Comparison of Linear voltage regulators and switching voltage regulators, Buck, Boost, Buck-Boost converters in Boundary and Discontinuous Conduction Mode (DCM), Isolated converters-unidirectional and bidirectional core excitation, Flyback converter, Forward converter, Full bridge converter **(Numericals).**	11
2.	**Design of DC to DC converters (Boost, Buck, BDC, Flyback only):** Review of magnetic concepts, area product, design of inductor, design of high frequency transformer, numerical on design of inductor and transformer. Selection of capacitor, switching device and diode.	07
3.	**Resonant converters:** Drawbacks of switch-mode converters, basic resonant circuit concepts, Resonant switch converters - ZVS, ZCS, comparison, Basic concept of resonant dc link inverter and Applications of resonant converters.	04
4.	**Modeling and control (Boost, Buck and Flyback only):** State space model of various dc to dc converters, effect of ESR of capacitor and inductor resistance on the state space models, state space averaging technique, small signal analysis, transfer function, feedback control, compensator design, voltage mode control and current mode control, advantages of digital control.	08

5.	**Multi-Level Inverter:** Need for multilevel inverters, Diode clamped, flying capacitor and cascaded MLI, Phase shifted and level shifted PWM techniques, introduction to SVM for three level inverter.	04
6.	**Applications of power electronic converters:** Solar PV power conditioning unit, Bidirectional converter in battery charging, Resonant converters in induction heating, converters in residential applications, Application of Multi level inverter and three port DC to Dc converters.	05

Self study Topics: series and parallel load resonant converter.

Note: Students should be encouraged to study the self-study topics through text books, reference books, online courses /contents etc. The students' performance on self-study contents be verified through MCQs and/or presentations or any other suitable methodology.

Books Recommended:

Text Books:

1. N. Mohan and T. M. Undeland, "Power Electronics: Converters, Applications and Design", John Wiley & Sons, 2007.
2. L. Umanand, Bhatt, "Design Of Magnetic Components for Switched Mode Power Converters", John Wiley & Sons.
3. Simon Ang, Alejandro Oliva, "Power-Switching Converters", Taylor and Francis group
4. Bin Wu, "High Power Converters and AC drives", IEEE press, John Wiley & Sons.
5. M.H. Rashid, Hand book of Power Electronics", Third edition Butterworth-Heinemann, 2011.

Reference Books:

1. L. Umanand, "Power Electronics: Essentials and Applications", Wiley India, 2009.
2. R.W. Erickson and D. Maksimovic, "Fundamentals of Power Electronics", Springer Science & Business Media, 2007.
3. Joseph Vithayathil, "Power Electronics", Tata McGraw hill, 1995.
4. P. T. Krein, Elements of Power Electronics, Oxford University Press.
5. V. Ramanarayanan, "Course Material on Switched Mode Power Conversion", 2007.
6. Simone Buso and Paolo Mattavelli "Digital Control in Power Electronics", Morgan & Claypool Publishers.

Website Reference/ Video Courses:

1. NPTEL Course: **Advance Power Electronics And Control** By Prof. Avik Bhattacharya, Dept. of Electrical Engineering, IIT Roorkee :-Web link- https://nptel.ac.in/courses/108/107/108107128/
2. NPTEL Course: **Switched Mode Power Conversion** By Prof. L. Umanand and Prof. V. Ramanarayanan, IISC Bangalore :-Web link- https://nptel.ac.in/courses/108/108/108108036/

Assessment:

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

Theory Examination:

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

ELECTRICAL ENGINEERING - SEMESTER-V						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits assigned		
EEDO5013	Advanced Measurements and Instrumentation	Theory	Pract./Tut.	Theory	Pract /Tut.	Total
		3	--	3	--	3

Course Code	Course Name	Examination Scheme							
		Theory					Term work	Pract / Oral	Total
		Internal Assessment			End Sem. Exam.	Exam. Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEDO5013	Advanced Measurements and Instrumentation	20	20	20	80	03	--	-	100

Course Objectives	1. To impart knowledge of architecture of the analog and digital measurement systems 2. To illustrate the working principle of electrical and non-electrical parameters measurements 3. To emphasize the principles and application of MEMS 4. To acquaint with digital data acquisition and virtual instrumentation system
Course outcomes	Upon successful completion of this course, the learner will be able to: 1. Classify, select and use various types of measurement sensors/ transducers and instrumentation system suitable for the given application 2. Classify and select proper measuring instrument for various electrical and non-electrical parameters measurements 3. Illustrate the principles and application of MEMS in various fields of engineering. 4. Understand the working of digital data acquisition system 5. Understand the role of virtual instrumentation in various application domains

Module	Contents	Hours
1	Measurement and Instrumentation: Basics of measurement and instrumentation system: Measurement System Architecture: analog and digital systems; Measuring Instruments: Classification, Absolute and secondary instruments, indicating instruments, constructional details, characteristics; Errors in measurements, Sensor Dynamics, Overview of Signal Conditioning: Analog and Digital Signal Conditioning	04
2	Sensors and Transducers: • **Electrical Parameters measurement:** Voltage and current, Instrument Transformers: Potential and current transformers. • **Displacement Measurement:** Transducers for displacement, displacement measurement, potentiometer, LVDT. • **Strain Measurement:** Theory of Strain Gauges, Bridge circuit, Strain gauge based load cells and torque sensors, • **Velocity, Speed, Vibration and Acceleration Measurement:** *Velocity and Speed*: Electromagnetic tachometer, Photoelectric tachometer, variable reluctance tachometer, Digital Encoders. *Vibration and acceleration*: Eddy current type, piezoelectric type; Accelerometer: Principle of working, practical accelerometers, strain gauge based and piezoelectric accelerometers. • **Pressure Measurement:** Elastic pressure transducers viz. Bourdon tubes, diaphragm, bellows and piezoelectric pressure sensors. • **Flow Measurement:** Bernoulli flowmeter, Ultrasonic flowmeter, Magnetic flow meter, Rotameter. • **Miscellaneous Sensors:** Leak detector, Flame detector, Smoke detector, pH sensors, Conductivity sensors, Humidity sensors, Potentiometric Biosensors and Proximity sensors **(Only basic principle of working)**	10

3	MEMS Technology: Introduction Nanotechnology and MEMS, MEMS design, and fabrication technology – Lithography, Etching, MEMS material, Bulk micromachining, Surface micromachining, Micro-actuator, electrostatic actuation, Micro-fluidics. *MEMS types and their applications:* Mechanical MEMS – Strain and pressure sensors, Accelerometers etc., Electromagnetic MEMS – Micro-motors, Wireless and GPS MEMS, Magnetic MEMS – all effect sensors, SQUID magnetometers, Optical MEMS – Micro-machined fiber optic component, Optical sensors, Thermal MEMS – thermo-mechanical and thermo-electrical actuators, Peltier heat pumps	10
4	Digital Data Acquisition System: Interfacing transducers to Electronics Control and Measuring System. Instrumentation and Isolation Amplifier; Review of Computer-Controlled Test Systems. IEEE-488 GPIB Bus; Microcontroller based data acquisition	04
5	Virtual Instrumentation: Historical perspective, Block diagram and Architecture of Virtual Instruments Data-flow Techniques: Graphical programming in data flow, Comparison with conventional programming. VI Programming Techniques: VIs and sub-VIs, Loops and Charts, Arrays, Clusters and graphs, Case and sequence structures, Formula nodes, Use of Analysis Tools: Advanced analysis tools such as Fourier transforms, Power spectrum, Correlation methods, Windowing and filtering and their applications in signal and image processing, Motion Control.	06
6	**Process Control System:** Electrical, Pneumatic, Hydraulic and Thermal systems, Process Control, Selection of Control: On-Off control, P, Pi, PID control. Sensitivity analysis of sensor-influence of component variation, Signal conditioning: Amplifier, Conversion, Filtering, Impedance Buffering, Modulation / Demodulation, Linearization, Grounding and Isolation.	05

Books Recommended:

Text Books and Reference Books:

1. Introduction To Instrumentation And Measurements by Robert B. Northrop, CRC Press, 2014
2. Instrumentation for Process Measurements and Control, by Norman Andrson, Chilton Company
3. Measurement Systems: Applications and Design, by EO Doebelin,5th Edition, McGraw Hill
4. Mechanical Engineering Measurements, A K Sawhney, Dhanpat Rai & Sons, New Delhi
5. Instrumentation & Mechanical Measurements, A K Thayal
6. Control System Engineering by Nagrath IJ and Gopal M, Wiley Eastern Ltd.
7. Control systems by Dhanesh Manik, Cengage Learning
8. Engineering Metrology and Measurements by N V Raghavendra and L Krishnamurthy, Oxford University Press
9. Instrumentation and Control System, W. Bolton, Elsevier
10. Smart Sensors and MEMS, by Stoyan Nihtianov and Antonio Luque, Woodhead Publishing, 2018.
11. Fundamentals of Micro-fabrications and Nanotechnology- From MEMS to Bio-Mems and Bio-NEMS, by Marc J. Madou, CRC Press, 2011
12. Handbook of Silicon Based MEMS Materials and Technologies, by Markku Tilli et al. William Andrew, Elsevier, 2015

Website Reference / Video Courses:

1. NPTEL Course: Electrical Measurement And Electronic Instruments By Prof. Avishek Chatterjee, Dept. of Electrical Engineering, IIT Kharagpur:- Web link- https://nptel.ac.in/courses/108/105/108105153/
2. NPTEL Course: Industrial Instrumentation By Prof. Alok Barua, IIT Kharagpur:-Web link- https://nptel.ac.in/courses/108/105/108105064/
3. NPTEL Course: Industrial Instrumentation By Prof. Prof. S. Mukhopadhyay and Prof. S.Sen, IIT Kharagpur:- Web link- https://nptel.ac.in/courses/108/105/108105062/

Assessment:

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

Theory Examination:

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

ELECTRICAL ENGINEERING - SEMESTER-V						
Course Code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEDO5014	Analog and Digital Communication	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		3	--	3		3

Course Code	Course Name	Examination Scheme							
		Theory					Term Work	Pract/ Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEDO5014	Analog and Digital Communication	20	20	20	80	3	-	-	100

Course Objectives	1. To introduce the elements of communication systems, describe the generalized block diagram and the types of communication systems. 2. To make students understand analog and digital communication techniques 3. To teach data and pulse communication techniques 4. To introduce source and Error control coding
Course Outcomes	Upon successful completion of this course, the learner will be able to: 1. Understand theory of noise and the various methods involved in modulation techniques 2. Interpret the concepts in analog communication and differentiate various analog modulation techniques. 3. Develop the concepts in digital communication and various digital modulation techniques 4. Apply and integrate various pulsed modulation in digital communication systems. 5. Conversant in proposing suitable error controlling and correction algorithms. 6. Understand and incorporate the basic knowledge of optical fiber communication and Satellite communication.

Module	Contents	Hours
1.	Introduction to Communication Systems : Need and Importance of Communication, Elements of a Communication System, Types of communication systems (block diagram approach), Electromagnetic Spectrum used in communication, concept of bandwidth and power, Receiver characteristics, Need for modulation; Noise: Source of Noise - Types of noise, External Noise- Internal Noise – Noise Calculation, signal to noise ratio	05
2.	Analog Communication: Theory of Amplitude Modulation(DSBFC, DSBSC) - Evolution and Description of SSB Techniques, Independent sideband (ISB) and Vestigial Side Band (VSB) principles and transmitters; Theory of Frequency and Phase Modulation ; Comparison of various Analog Communication System (AM, FM, PM)	08
3.	Digital Communication: Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying (PSK), BPSK,QPSK, Quadrature Amplitude Modulation (QAM); Bandwidth, Efficiency Comparison of various Digital Communication System (ASK – FSK – PSK – QAM).	07

4.	**Sampling Techniques:** Sampling theorem, Nyquist criteria; Types of Sampling. Pulse modulation schemes – PAM, PPM and PWM generation and detection-Pulse code modulation. Conversion of PWM to PPM. Multiplexing Techniques - FDM and TDM; Delta modulation, adaptive delta modulation, principle, generation and detection; TDM and FDM basic concepts and block diagram; Applications of pulse communication	07
5.	**Source and Error Control Coding:** Entropy -Source encoding theorem - Shannon fano coding - Huffman coding - mutual information – Channel capacity - Channel coding theorem; Error Control Coding - Linear block codes - Cyclic codes –Convolution codes - Viterbi decoding algorithm.	08
6.	**Overview of other Types of Communication:** Optical fiber communication; Satellite Communication; Bluetooth.	04

Text Books:-

1. G. Kennedy and B. Davis, "Electronic Communication Systems", Tata McGraw Hill, 2011
2. Roddy and Coolen, "Electronic Communication", 4th Edition, Pearson Education 2008
3. Simon Haykin, "Digital Communications", 2014, 1st edition, John Wiley, India.
4. T.L.Singal, "Analog and Digital Communication", 2012, 1st edition, Tata McGraw Hill Education Private Ltd, New York.

Reference Books:

1. Taub and Schilling, "Principles of Communication Systems", McGraw Hill, Fourth reprint 2009.
2. Wayne Tomasi, "Electronic Communications Systems – Fundamentals Through advanced", 5th Ed., Pearson Education, 2009.
3. Hwei Ksu and Debjani Mitra, "Analog and Digital Communication: Schaum's Outline Series",
4. McGraw Hill Education (India) Pvt Ltd., 3rd Edition 2009.
5. John. G. Proakis, "Digital Communication", 2014, 5th edition, Pearson Education, Noida, India.
6. Herbert Taub and Donald L Schilling," Principles of Communication Systems", Tata McGraw Hill, New Delhi, 2012
7. Bernard Sklar, "Digital Communications: Fundamentals and Applications", 2016, 2nd edition, Prentice Hall, New Jersey, US.

Website Reference / Video Courses:

1. NPTEL Course: **Principles of Digital Communications** By Prof. S N Merchant, Dept. of Electrical Engineering, IIT Bombay:- Web link- https://nptel.ac.in/courses/108/101/108101113/
2. NPTEL Course: **Principles of Communication Systems-I** By Prof. Aditya K. Jagannatham, IIT Kanpur:-Web link- https://nptel.ac.in/courses/108/104/108104091/

Assessment:

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

Theory Examination:

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

ELECTRICAL ENGINEERING - SEMESTER-V						
Course Code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEL501	Electrical AC Machines Lab-II	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		--	2		1	1

Course Code	Course Name	Examination Scheme							
		Theory					Term Work	Pract & Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEL501	Electrical AC Machines Lab-II	---	---	---	---	--	25	25	50

Course Objectives	**To impart the knowledge on the following :** 1. Practical understanding of Synchronous machines and their characteristics 2. Voltage regulation and Parallel operation of Synchronous generators
Course outcomes	Upon successful completion of this course, the learner will be able : 1. To analyze the operation of synchronous machines 2. To determine the voltage regulation of synchronous machines 3. To analyze the synchronization (or parallel operation) of synchronous machines 4. To determine the parameters of synchronous machines

Syllabus: Same as EEC501: Electrical AC Machines-II

Suggested List of Laboratory Experiments: Minimum six experiments need to be performed.

1. Constructional details of Synchronous machine
2. Voltage regulation of Alternator by Direct loading method
3. Voltage regulation of Alternator by EMF and MMF method
4. Voltage regulation of Alternator by ZPF and ASA method
5. Synchronization / Parallel operation of Alternator
6. Starting methods of Synchronous motor
7. Load test on Synchronous motor
8. 'V' and 'inverted V' curves of Synchronous machine
9. Determination of X_d and X_q of Synchronous machine by Slip test
10. Use of Synchronous motor as a Synchronous condenser
11. To determine positive sequence, negative sequence and zero sequence reactance of an alternator

Any other experiment based on syllabus which will help students to understand topic / concept.

Industry Visit: Students' visit to be arranged to the nearby industry involved in design/ manufacturing/ processing in the following electrical engineering domains: Electrical Machines / Electrical Power / Renewable energy / Power Electronics / Instrumentation / Communication Systems. All students shall submit visit report in appropriate format as a part of the submission for EEL501.

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

Virtual Lab Website Reference

1. http://vlab.co.in/broad-area-electrical-engineering
2. http://vlab.co.in/broad-area-electronics-and-communications

Term work:

Term work shall consist of minimum eight experiments. The distribution of marks shall be as follows:

Experiments Performance	: 10 marks
Journal	: 05 marks
Industrial Visit report	: 05 marks
Attendance (Theory and Practical)	: 05 marks

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

Practical and Oral Examination:

Practical and Oral examination will be based on entire syllabus of **EEC501: Electrical AC Machines-II**

ELECTRICAL ENGINEERING - SEMESTER-V						
Course code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEL502	Simulation Lab-II	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		--	2		1	1

Course code	Course Name	Examination Scheme							
		Theory					Term Work	Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEL502	Simulation Lab-II	---	---	---	---	--	25	25	50

Course Objectives	The course is aimed: 1. To understand basic block sets of different simulation platform used in electrical /electronic circuit design. 2. To understand use and coding in different software tools used in electrical/ electronic circuit design
Course outcomes	Upon successful completion of this course, the learner will be able to 1. Develop the skill to use the software packages to model and program electrical and electronics systems 2. Model different electrical and electronic systems and analyze the results 3. Articulate importance of software packages used for simulation in laboratory experimentation /research/industry by analyzing the simulation results. 4. Simulate circuits for performance analysis.

Suggested Software Tools to be Used for Simulation Lab-II:

Note:

1. Students should be encouraged to use open source softwares such as SCILAB, LTSPICE, Texas Instrument's 'Webbench', Ngspice, Solve Elec etc. for carrying out the lab simulation listed below.
2. Use of Professional Licensed versions of softwares like MATLAB, Proteus, LabVIEW, NI Multisim, PSpice, PSim, PSCAD, TINA etc. is also allowed.
3. Use of 'Python' platform for simulating components/ circuit behaviour should also be emphasized
4. Many of the following suggested experimentation can be carried out on Virtual lab platform

Suggested List of Laboratory Experiment: Minimum eight experiments need to be performed from various subjects domain. Some of the simulation experiments can also be selected based on the department elective offered

1. Study of sampling theorem, effect of under-sampling.
2. Study of Quantization of continuous-amplitude, discrete-time analog signals.
3. Study of properties of Linear time-invariant system.
4. Simulation of Signal processing circuit (amplifier/ filter /linearizing circuits) used for sensors / transducers
5. Virtual Instrumentation based Simulations of measurement and processing of Non-electrical parameters like temperature, pressure, force, speed etc.
6. Virtual Instrumentation based Simulation of any suitable industrial Process
7. Simulate the performance of a chemical sensor
8. Characterize the strain gauge sensor
9. Characterize the temperature sensor (Thermocouple)
10. Characterize the temperature sensor (RTD)
11. Simulate the performance of a bio-sensor
12. Measurement of level in a tank using capacitive type level probe

13. Simulation of Solar PV MPPT (P&O or Incremental conductance) based characterization under different operating conditions
14. Simulation of Solar PV and Battery hybrid energy source
15. Simulation of Fuel cell based Two stage (DC-DC converter and VSI) power supply for AC loads
16. Simulation of Back to back converter for Wind Energy Application
17. Simulation of closed loop control of Buck/Boost/Buck-Boost DC-DC converters
18. Simulation of a Resonant converter (Series/ parallel; ZVS/ZCS)
19. Simulation of Multilevel Inverter
20. Simulation of Solar PV MPPT converter with VSI
21. Simulation of Battery based Bidirectional Converter
22. Simulation of Flyback converter based SMPS
23. Simulating a Local Area Network (Using Vlab platform: Advanced Network Technologies Virtual Lab)
24. Simulating a Wi-Fi Network (Using Vlab platform: Advanced Network Technologies Virtual Lab)
25. Simulating a Wi-Fi Network (Using Vlab platform: Advanced Network Technologies Virtual Lab)
26. Setting up a Bluetooth Network (Using Vlab platform: Advanced Network Technologies Virtual Lab)
27. Setting up a ZigBee Network (Using Vlab platform: Advanced Network Technologies Virtual Lab)
28. Simulating a Wireless Sensor Network (Using Vlab platform: Advanced Network Technologies Virtual Lab)

Any other simulations / algorithms based on fifth semester syllabus, which will help students to understand topic / concept.

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

Virtual Lab Website Reference

1. http://vlab.co.in/broad-area-electrical-engineering
2. http://vlab.co.in/broad-area-electronics-and-communications

Term work:

Term work shall consist of minimum eight experiments. The distribution of marks shall be as follows:

Experiments Performance	: 10 marks
Journal	: 10 marks
Attendance (Theory and Practical)	: 05 marks

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

Oral Examination:

Oral examination will be based on all the laboratory experiments carried out in **EEL-502- Simulation Lab-II**

ELECTRICAL ENGINEERING - SEMESTER-V						
Course code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEL503	Control Systems Lab	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		--	2		1	1

Course code	Course Name	Examination Scheme							
		Theory					Term Work	Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEL503	Control Systems Lab	---	---	---	---	--	25	25	50

Course Objectives	1. To study basic concepts of control system 2. To familiarize with the modelling of dynamical systems and the characteristics of control components like AC servo motor, DC servo motor, DC position control system and synchro 3. To employ time domain analysis to predict and diagnose transient performance parameters of the system for standard input functions to ascertain the required dynamic response from the system
Course outcomes	Upon successful completion of this course, the learner will be able to 1. Illustrate the functioning of various components of control system. 2. Analyse the response of physical system for various inputs. 3. Analyze and interpret stability of the system through Root Locus, Bode plot and Nyquist plots 4. Execute time response analysis of a second order control system using MATLAB

Syllabus: Same as EEC503: Control Systems

Suggested List of Laboratory Experiments: Minimum four from Group (A) and four from Group (B), in all minimum eight experiments need to be performed.

(A) Laboratory Experiments

1. Study of AC Servomotor
2. Study of DC Servomotor
3. Study of potentiometer as an error detector
4. Study of Synchros as an error detector
5. Study of AC position control system
6. Study of DC position control system
7. Obtain time response of first order to step ramp and parabolic input
8. Obtain time response of second order system to step input.

(B) Simulation Based Experiments (on Simulation Platform like MATLAB/SCILAB or Python Programming tool)

1. a) Simulation of a typical second order system and determination of step response and evaluation of time domain specifications
   b) Evaluation of the effect of additional poles and zeroes on time response of second order system
   c) Evaluation of effect of pole location on stability
   d) Effect of loop gain of a negative feedback system on stability
2. Draw the Root loci for a given transfer function and verification of breakaway point and imaginary axis crossover point.
3. Obtain the phase margin and gain margin for a given transfer function by drawing bode plots and verify the same.
4. Draw the Nyquist plot for a given transfer function.

5. Obtain State model from Poles and zero and also from transfer function
6. Determination of step, ramp & impulse response of a state model

Any other experiment based on syllabus which will help students to understand topic / concept.

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

Virtual Lab Website Reference

1. http://vlab.co.in/broad-area-electrical-engineering
2. http://vlab.co.in/broad-area-electronics-and-communications

Term work:

Term work shall consist of minimum eight experiments. The distribution of marks shall be as follows:

Experiments Performance :10 marks
Journal :10 marks
Attendance (Theory and Practical) :05 marks

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

Oral Examination:

Oral examination will be based on entire syllabus of **EEC503: Control Systems**

ELECTRICAL ENGINEERING - SEMESTER-V								
Course Code	Course Name	Teaching scheme			Credit assigned			
EEL504	Professional Communication & Ethics-II	Theory	Pract.	Tut.	Theory	Pract.	Tut.	Total
		--	2*+ 2 Hours (Batch-wise)	--	--	2	--	02

*Theory class to be conducted for full class.

Course Code	Course Name	Examination Scheme									
		Theory					Term work	Pract	Oral	Internal Oral	Total
		Internal Assessment			End sem	Duration (hrs)					
		Test 1	Test 2	Avg.							
EEL504	Professional Communication & Ethics-II	--	--	--	--	--	25	--	--	25	50

Course Rationale	This curriculum is designed to build up a professional and ethical approach, effective oral and written communication with enhanced soft skills. Through practical sessions, it augments student's interactive competence and confidence to respond appropriately and creatively to the implied challenges of the global Industrial and Corporate requirements. It further inculcates the social responsibility of engineers as technical citizens.
Course Objectives	• To discern and develop an effective style of writing important technical/business documents. • To investigate possible resources and plan a successful job campaign. • To understand the dynamics of professional communication in the form of group discussions, meetings, etc. required for career enhancement. • To develop creative and impactful presentation skills. • To analyze personal traits, interests, values, aptitudes and skills. • To understand the importance of integrity and develop a personal code of ethics.
Course Outcomes	**Upon successful completion of this course, the learner will be able to:** 1. Plan and prepare effective business/ technical documents which will in turn provide solid foundation for their future managerial roles. 2. Strategize their personal and professional skills to build a professional image and meet the demands of the industry. 3. Emerge successful in group discussions, meetings and result-oriented agreeable solutions in group communication situations. 4. Deliver persuasive and professional presentations. 5. Develop creative thinking and interpersonal skills required for effective professional communication. 6. Apply codes of ethical conduct, personal integrity and norms of organizational behaviour.

Module	Contents	Hours
1	ADVANCED TECHNICAL WRITING :PROJECT/PROBLEM BASED LEARNING (PBL) 1.1 Purpose and Classification of Reports: Classification on the basis of: • Subject Matter (Technology, Accounting, Finance, Marketing, etc.) • Time Interval (Periodic, One-time, Special) • Function (Informational, Analytical, etc.) • Physical Factors (Memorandum, Letter, Short & Long)	06

	1.2. Parts of a Long Formal Report: • Prefatory Parts (Front Matter) • Report Proper (Main Body) • Appended Parts (Back Matter) 1.3. Language and Style of Reports • Tense, Person & Voice of Reports • Numbering Style of Chapters, Sections, Figures, Tables and Equations • Referencing Styles in APA & MLA Format • Proofreading through Plagiarism Checkers 1.4. Definition, Purpose & Types of Proposals • Solicited (in conformance with RFP) & Unsolicited Proposals • Types (Short and Long proposals) 1.5. Parts of a Proposal • Elements • Scope and Limitations • Conclusion 1.6. Technical Paper Writing • Parts of a Technical Paper (Abstract, Introduction, Research Methods, Findings and Analysis, Discussion, Limitations, Future Scope and References) • Language and Formatting • Referencing in IEEE Format	
2	EMPLOYMENT SKILLS 2.1. Cover Letter & Resume • Parts and Content of a Cover Letter • Difference between Bio-data, Resume & CV • Essential Parts of a Resume • Types of Resume (Chronological, Functional & Combination) 2.2 Statement of Purpose • Importance of SOP • Tips for Writing an Effective SOP 2.3 Verbal Aptitude Test • Modelled on CAT, GRE, GMAT exams 2.4. Group Discussions • Purpose of a GD • Parameters of Evaluating a GD • Types of GDs (Normal, Case-based & Role Plays) • GD Etiquettes 2.5. Personal Interviews • Planning and Preparation • Types of Questions • Types of Interviews (Structured, Stress, Behavioural, Problem Solving & Case-based) • Modes of Interviews: Face-to-face (One-to one and Panel) Telephonic, Virtual	06
3	BUSINESS MEETINGS 3.1 Conducting Business Meetings • Types of Meetings • Roles and Responsibilities of Chairperson, Secretary and Members • Meeting Etiquette 3.2. Documentation • Notice • Agenda • Minutes	02

4	TECHNICAL/ BUSINESS PRESENTATIONS 4.1 Effective Presentation Strategies • Defining Purpose • Analyzing Audience, Location and Event • Gathering, Selecting &Arranging Material • Structuring a Presentation • Making Effective Slides • Types of Presentations Aids • Closing a Presentation • Platform skills 4.2 Group Presentations • Sharing Responsibility in a Team • Building the contents and visuals together • Transition Phases	02
5	INTERPERSONAL SKILLS 5.1 Interpersonal Skills • Emotional Intelligence • Leadership & Motivation • Conflict Management & Negotiation • Time Management • Assertiveness • Decision Making 5.2 Start-up Skills • Financial Literacy • Risk Assessment • Data Analysis (e.g. Consumer Behaviour, Market Trends, etc.)	08
6	CORPORATE ETHICS 6.1 Intellectual Property Rights • Copyrights • Trademarks • Patents • Industrial Designs • Geographical Indications • Integrated Circuits • Trade Secrets (Undisclosed Information) 6.2 Case Studies • Cases related to Business/ Corporate Ethics	02

List of assignments:

(In the form of Short Notes, Questionnaire/ MCQ Test, Role Play, Case Study, Quiz, etc.)

1. Cover Letter and Resume
2. Short Proposal
3. Meeting Documentation
4. Writing a Technical Paper/ Analyzing a Published Technical Paper
5. Writing a SOP
6. IPR
7. Interpersonal Skills
8. Aptitude test (Verbal Ability)

Note:

1. The Main Body of the project/book report should contain minimum 25 pages (excluding Front and Back matter).
2. The group size for the final report presentation should not be less than 5 students or exceed 7 students.

3. There will be an end–semester presentation based on the book report.

Assessment:

Term Work:
Term work shall consist of minimum 8 experiments.
The distribution of marks for term work shall be as follows:
Assignment : 10 Marks
Attendance : 5 Marks
Presentation slides : 5 Marks
Book Report (hard copy) : 5 Marks
The final certification and acceptance of term work ensures the satisfactory performance of laboratory work and minimum passing in the term work.

Internal oral:

Oral Examination will be based on a GD & the Project/Book Report presentation.

Group Discussion : 10 marks
Project Presentation : 10 Marks
Group Dynamics : 5 Marks

Books Recommended:
Textbooks and Reference books:

1. Arms, V. M. (2005). *Humanities for the engineering curriculum: With selected chapters from Olsen/Huckin: Technical writing and professional communication, second edition*. Boston, MA: McGraw-Hill.
2. Bovée, C. L., &Thill, J. V. (2021). *Business communication today*. Upper Saddle River, NJ: Pearson.
3. Butterfield, J. (2017). *Verbal communication: Soft skills for a digital workplace*. Boston, MA: Cengage Learning.
4. Masters, L. A., Wallace, H. R., & Harwood, L. (2011).*Personal development for life and work*. Mason: South-Western Cengage Learning.
5. Robbins, S. P., Judge, T. A., & Campbell, T. T. (2017). *Organizational behaviour*. Harlow, England: Pearson.
6. Meenakshi Raman, Sangeeta Sharma (2004) Technical Communication, Principles and Practice. Oxford University Press
7. Archana Ram (2018) Place Mentor, Tests of Aptitude For Placement Readiness. Oxford University Press
8. Sanjay Kumar &PushpLata (2018). Communication Skills a workbook, New Delhi: Oxford University Press.

ELECTRICAL ENGINEERING - SEMESTER-V						
Course Code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEM501	Mini Project – 2A	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		--	4$	--	2	2

Course code	Course Name	Examination Scheme							
		Theory					Term Work	Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEM501	Mini Project – 2A	--	--	--	--	--	25	25	25

$ indicates work load of Learner (Not Faculty)

Course Objectives	1. To design and develop a moderately complex electrical/electronic/digital circuit with practical applications. 2. To understand basic concepts of circuit design while developing the project. 3. To enable the students to gain hands-on experience independently proposing and implementing the project and thus acquire the necessary confidence to deal with complex electrical/electronic/digital systems.
Course Outcomes	Upon successful completion of this course, the learner will be able to: 1. Identify problems based on societal /research needs. 2. Apply Knowledge and skill to solve societal problems in a group. 3. Develop interpersonal skills to work as member of a group or leader. 4. Draw the proper inferences from available results through theoretical/ experimental/ simulations. 5. Analyse the impact of solutions in societal and environmental context for sustainable development. 6. Use standard norms of engineering practices 7. Excel in written and oral communication. 8. Demonstrate capabilities of self-learning in a group, which leads to life-long learning. 9. Demonstrate project management principles during project work

A. <u>Mini Project -Topic Selection and Approval</u>

1. The group may be of maximum **FOUR (04)** students.
2. Students should propose project ideas & finalize the project idea in consultation with guide/ HOD. Students should select a problem which addresses some basic home, office or other real life applications. The mini project must have hardware part. The software part is optional.
3. Students should identify different components/ devices, instruments, simulation/emulations software tools required for the project.
4. Students should submit implementation plan in the form of Gantt/ PERT/ CPM chart, which will cover weekly activity of project.
5. A Log Book to be prepared by each group to record the work progress in terms of milestones per week by students. Weekly comment, remarks to be put by guiding faculty.

B. Mini Project –Execution

i. Design and Fabrication

a. Initial fabrication of the project by students can be done using standard devices/material/software tools to verify the circuit functionalities Initial project fabrication and testing is expected to be done by soldering/assembling on general purpose PCB/ Bakelite boards or suitable platforms required for the electrical/electronic/digital components. Discourage the use of breadboards.
b. If essential, use of a simulation/ emulation software tools to test and verify the performance of the circuit should be encouraged.
c. Students should prepare the proper drawings (electrical/ mechanical), schematics/ layouts of the project.
d. For final implementation of the circuit, preparation of PCB (if any required) using suitable CAD tools and fabricating the same in the lab is expected.

ii. Devices/ Components/ Systems to be Used:

Students are encouraged to use passive components like resistors, capacitors, inductors etc. If any specialize inductor is not readily available, the fabrication of the same in the lab should be encouraged. Other components like: Transistors, diodes, voltage regulators, logic gates, Op-amps, general purpose microcontroller, DC motors/ AC motors, sensors, actuators, relays etc. (Students may add more components as per the requirement of project).

iii. Testing and analysis of the Project

Students should test the circuit using suitable laboratory equipments like power supply, multi-meter, CRO, DSO etc. In case of any debugging requirement, students should record the problems faced during the testing and solutions sought after for the fault in the circuit.

All the testing results must be well documented in the final project report verifying the functionalities of the propose project.

iv. Use of Reference Material/Literature :

Students are advised to refer Application Notes, research publications & data sheets of various electrical/electronic/digital devices from Texas Instruments, Microchips, International Rectifiers, ST Microelectronics, Philips, NXP and many other manufacturers.

C. Project Report Format:

Mini Project report should include circuit diagram, operation, application, design details, testing, waveforms (if applicable) references, simulation results and final prepared PCB image, conclusion, etc. Project report should include report of all above steps listed in (2) and the conclusion.

Note:-

It is expected that the department should organise some of the guidance expert lectures / video lectures/ courses/ webinars/ workshops etc. for the students at the appropriate timing during the Mini Project practical slots on following topics:

1) Understanding passive components viz. resistors, capacitors and inductors from practical point of view: types/ varieties, device packages, applications and cost.
2) Understanding semiconductor components viz. diodes, BJT and JFET/MOSFETs from practical point of view: types/ varieties, device packages, applications and cost.
3) Design principles of simple electrical / electronic circuits with some examples.
4) Selection of switches and circuit protection components.
5) Selection and sizing of wires and conductors.
6) Soldering Practice.
7) Heat-sinking and Enclosure design concepts
8) Overall workmanship while working on the project fabrication.
9) Use of different software tools for design and development of circuits
10) Use of standard as well as some of the advanced laboratory equipments needed for testing of such projects

Application Domains:

List of key application domains from where students are encouraged to derive Mini Projects topics:

1) Smart Agriculture solutions
2) Power converter applications in various Applications
3) IoT based applications in power systems
4) AI/ML applications in disaster management
5) Renewable Energy
6) Energy Conservation
7) Energy Storage
8) Battery Charging and Protection
9) Fire Safety
10) Electrical System Protection
11) Lighting Control
12) Wireless Power Transfer
13) Electrical Components Testing
14) Electrical Parameters Measurement
15) Non-conventional Electricity Generation
16) Laboratory Equipments
17) E-Mobility / Electric Vehicles
18) Video Surveillance Systems
19) Robotics for Hazardous applications
20) Waste Management System
21) Smart City Solutions
22) Smart Classrooms and learning Solutions
23) Design of Electrical Equipment
24) PLC based automation system
25) Power system Monitoring System (EMS)

It is every much expected that the complexity of the Mini Project 2A/ 2B should be increased compared to the selection of projects during Mini Project 1A/1B. Also based on the subjects learned in Sem. III and Sem. IV the broader area inclusive of the concepts learned must be selected. Students can identify the mini project topics either from above suggested domains or any other relevant electrical engineering domains. The inter-disciplinary nature of the project is also desirable.

Guidelines for Assessment of Mini Project:

Term Work

- The review/ progress monitoring committee shall be constituted by head of departments of each institute. The progress of mini project to be evaluated on continuous basis, minimum two reviews in each semester.
- In continuous assessment focus shall also be on each individual student, assessment based on individual's contribution in group activity, their understanding and response to questions.
- Distribution of Term work marks for both semesters shall be as below;
  - Marks awarded by guide/supervisor based on log book : 10
  - Marks awarded by review committee : 10
  - Quality of Project report : 05

Review/progress monitoring committee may consider following points for assessment based on either one year or half year project as mentioned in general guidelines.

One-year Mini Project:

- In first semester entire theoretical solution shall be ready, including components/system selection and cost analysis. Two reviews will be conducted based on presentation given by students group.

- First shall be for finalization of problem
- Second shall be on finalization of proposed solution of problem.

- In second semester expected work shall be procurement of components /systems, building of working prototype, testing and validation of results based on work completed in an earlier semester.
  - First review is based on readiness of building working prototype to be conducted.
  - Second review shall be based on poster presentation cum demonstration of working model in last month of the said semester.

Half-year Mini Project:

- In this case in one semester students' group shall complete project in all aspects including,
  - Identification of need/problem
  - Proposed final solution
  - Procurement of components/systems
  - Building prototype and testing
- Two reviews will be conducted for continuous assessment,
  - First shall be for finalization of problem and proposed solution
  - Second shall be for implementation and testing of solution.

Assessment criteria of Mini Project.

Mini Project shall be assessed based on following criteria;

1. Quality of survey/ need identification
2. Clarity of Problem definition based on need.
3. Innovativeness in solutions
4. Feasibility of proposed problem solutions and selection of best solution
5. Cost effectiveness
6. Societal impact
7. Innovativeness
8. Cost effectiveness and Societal impact
9. Full functioning of working model as per stated requirements
10. Effective use of skill sets
11. Effective use of standard engineering norms
12. Contribution of an individual's as member or leader
13. Clarity in written and oral communication

- In one year, project, first semester evaluation may be based on first six criteria's and remaining may be used for second semester evaluation of performance of students in mini project.
- In case of half year project all criteria's in generic may be considered for evaluation of performance of students in mini project.

Guidelines for Assessment of Mini Project Oral Examination:

- Report should be prepared as per the guidelines issued by the University of Mumbai.
- Mini Project shall be assessed through a presentation and demonstration of working model by the student project group to a panel of Internal and External Examiners preferably from industry or research organizations having experience of more than five years approved by head of Institution.
- Students shall be motivated to publish a paper based on the work in Conferences/students competitions.

Oral Examination:

Mini Project shall be assessed based on following points:

1. Quality of problem and Clarity
2. Innovativeness in solutions
3. Cost effectiveness and Societal impact
4. Full functioning of working model as per stated requirements
5. Effective use of skill sets
6. Effective use of standard engineering norms
7. Contribution of an individual's as member or leader
8. Clarity in written and oral communication

Reference Books:

1. P. Horowitz and W. Hill, "The Art of Electronics", 3rd Edition, Cambridge University Press, 2015
2. R. S. Khandpur, "Printed Circuit Board", McGraw-Hill Education; 1st edition, 2005.
3. Simon Monk, "Hacking Electronic: Learning Arduino and Raspberry Pi", McGraw-Hill Education TAB; 2 edition (September 28, 2017).
4. Matthew Scarpino, Designing Circuit Boards with EAGLE: Make High-Quality PCBs at Low Cost, 1st Edition Prentice Hall.
5. P. Horowitz and W. Hill, The Art of Electronics, 3 Edition, Cambridge University Press.
6. Archambeault and D. James, PCB Design for Real-World EMI Control, Springer Publications
7. Mitzner, Kraig, "Complete PCB design using OrCAD Capture and PCB", Elsevier, 2009
8. Peter Dalmaris, "Kicad Like a Pro", Tech exploration
9. Charles Platt, "Encyclopedia of Electronic Components – Vol-1: Power, electromagnetism, and discrete semiconductors. ", Maker Media, 2012
10. Charles Platt, "Encyclopedia of Electronic Components – Vol-2: Integrated circuits, light sources, sound sources, heat sources, and high frequency sources. ", Maker Media, 2015

Suggested Software tools:

1. LTspice:https://www.analog.com/en/design-center/design-tools-and-calculators/ltspice-simulator.html#
2. Eagle : https://www.autodesk.in/products/eagle/overview
3. OrCAD: https://www.orcad.com/
4. Multisim : https://www.multisim.com/
5. Webbench: http://www.ti.com/design-resources/design-tools-simulation/webench-power-designer.html
6. Tinkercad : https://www.tinkercad.com/
7. Raspbian OS: https://www.raspberrypi.org/downloads
8. Arduino IDE: https://www.arduino.cc/en/main/software

Online Repository:

1. https://www.electronicsforu.com
2. https://circuitdigest.com
3. https://www.electronicshub.org
4. Github

ELECTRICAL ENGINEERING SEM-VI						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Tutorial	Theory	Tutorial	Total
EEC601	Power System Protection and Switchgear	3	-	3	-	3

Course Code	Course Name	Examination Scheme						
		Theory					Term Work	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)		
		Test 1	Test 2	Avg.				
EEC601	Power System Protection and Switchgear	20	20	20	80	03	-	100

Course Objectives	• To impart basic knowledge of power system protection, substation equipment and protection schemes.
Course Outcomes	Upon successful completion of this course, the learner will be able to: 1. To select the appropriate switching/protecting device for substations. 2. To discriminate between the application of circuit breaker and fuses as a protective device. 3. To understand the basic concept of relay, types of relay and their applications in power system. 4. To select the specific protection required for different components of power system according to the type of fault. 5. To apply the specific protection provided for different types of transmission lines.

Module	Contents	Hours
1	Substation Equipment and switching devices **Substation Equipment:** Instrument Transformers: Role of instrument transformers in measuring and protection, difference between measuring and protection CTs, selection of technically suitable instrument transformers; **Switchgear**-Definition, Types, Location of switchgear in typical power system, single line diagram to show the measuring and protection scheme **Switching Devices**- Isolator & Earthing switch (Requirements & definitions, types and construction, Pantograph Isolators, Ratings), Load break switches- Ratings and applications; Contactors- Basic working principle, Terms & Definitions, applications.	03
2	Circuit Breakers and Fuses: **Circuit Breaker:** Arc initiation, arc quenching principles, Re-striking voltage, RRRV, Recovery voltage, Types of Circuit Breakers: For LV application- MCB, MCCB, ELCB, air circuit breakers. For HV application- SF6 circuit breakers, vacuum circuit breakers (working principle, Construction, operating mechanisms, ratings & applications), Mechanical life, Electrical life and testing of circuit breakers. Principle and applications of LV and HV DC circuit breakers **Fuses & their applications**-Introduction, classification, working principle and applications of re-wirable and HRC fuses, Expulsion and drop out fuses, Fusing factor, selection of fuse link and cut off characteristics	10
3	Introduction to Protective relaying: Shunt & Series Faults, causes and Effects of faults, Importance of protective relaying, Protective zones, primary & Back-up protection, Different types of backup protection, desirable qualities of protective relaying, PSM & TSM(Importance, Different types of Time-current characteristics and application), working principle of **Electromagnetic Induction disc Relays,** Thermal, bimetal relays, Frequency relays, under/over voltage relays, DC relays,	09

	Different Principles of protection - Over current & earth fault (non- directional & directional types), differential protection(current and voltage type), distance protection (Working Principle and application of Impedance relay, Causes and remedies of Over reach-under reach, Reactance and Mho relay, Power swing blocking relay).	
4	**Protection Schemes Provided for major Apparatus:** **Generators** - Stator side (Differential, Restricted Earth fault, protection for 100% winding, Negative phase sequence, Reverse power, turn-turn fault), Rotor side (Field suppression, field failure, Earth fault, turn to turn fault) **Transformers**-Differential protection for star delta Transformer, Harmonic restraint relay, REF protection, Protection provided for incipient faults (Gas actuated relay). **Induction motors** - Protection of motor against over load, short circuit, earth fault, single phasing, unbalance, locked rotor, phase reversal, under voltage, winding temperature, Protection co-ordination	06
5	**Protection of Transmission Lines:** Feeder protection - Time grading, current grading, combined time & current grading protection provided for Radial, Ring Main, Parallel, T- Feeder. Bus Zone Protection - Differential protection provided for different types of bus zones. LV, MV, HV Transmission Lines - Protection provided by over current, earth fault, Differential and Stepped distance protection. EHV & UHV Transmission lines - Type and nature of faults, Need for auto-reclosure schemes, Carrier aided distance protection (Directional comparison method), Power Line Carrier Current protection (Phase comparison method). Introduction to the concept of Islanding	06
6	**Introduction to Static & Numerical Relays:** **Static Relays**- Introduction, Definition, Advantages and Disadvantages, Application of op-amps, logic gates, DSP, in static/ digital Relays. Relays as comparators (Amplitude & phase), **Numerical Relays**- Introduction, Block diagram of numerical relay, Signal sampling, Anti –Aliasing Filter, Introduction to the concept of Phase Measurement Unit	05

Books Recommended:

Text Books:

1. Switchgear & Protection by Sunil.S.Rao, Khanna Publications
2. Power system Protection & Switchgear by Badriram Vishwakarma, TMH
3. Power System Protection And Switchgear by Bhuvanesh A O, Nirmal CN, Rashesh PM, Vijay HM, Mc Graw Hill

Reference Books:

1. Fundamentals of protection by Paithanker & Bhide.S.R, P.H.I
2. Static Relays by Madhava Rao, TMH
3. A text book on Power System Engineering by Soni, Gupta, Bhatnagar & Chakraborthi, Dhanpat Rai & Co
4. Protective Relaying by Lewis Blackburn, Thomas.J.Domin
5. Power System Protection by P.M. Anderson, Wiley Interscience
6. Modern Power System Protection – Divyesh Oza, TMH Publication

Website Reference / Video Courses:

1. **NPTEL Course: Power System Protection** By Prof. S.A. Soman, Dept. of Electrical Engineering, IIT Bombay:- Web link- https://nptel.ac.in/courses/108/101/108101039/
2. **NPTEL Course: Power System Protection and Switchgear** By Prof. **Bhaveshkumar Bhalja**, Dept. of Electrical Engg, IIT Roorkee:- Web link- https://nptel.ac.in/courses/108/107/108107167/
3. **NPTEL Course: Power System Protection** By Prof. **Ashok Kumar Pradhan**, Dept. of Electrical Engineering, IIT Kharagpur:- Web link- https://nptel.ac.in/courses/108/105/108105167/

Assessment:

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

Theory Examination:

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

ELECTRICAL ENGINEERING SEM-VI						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Tutorial	Theory	Tutorial	Total
EEC602	Microcontroller Applications	3	-	3	-	3

Course Code	Course Name	Examination Scheme							
		Theory					Term Work	Pract/ Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)			
		Test 1	Test 2	Avg.					
EEC602	Microcontroller Applications	20	20	20	80	03	-	-	100

Course Objectives	1. To understand the features and architecture of PIC 18 microcontroller. 2. To introduce assembly programming knowledge for PIC 18 microcontroller. 3. To impart embedded programming knowledge for PIC 18 microcontroller using C. 4. To introduce various applications using microcontroller based system
Course Outcomes	Upon successful completion of this course, the learner will be able to: 1. To analyse the difference between microprocessor and microcontroller based systems. 2. To write, debug and execute the software programs for internal peripheral devices of microcontroller. 3. To write, debug and execute the software programs for external peripheral devices for microcontroller based systems. 4. To design and implement the peripheral devices interfacing with microcontroller

Module	Contents	Hours
1.	**Introduction to Microcontroller** Block diagram of generic microcontroller, Microcontroller versus Microprocessor, A brief history of PIC microcontroller, Overview of PIC 18 family and features, Internal Bus structure of PIC microcontroller, Clock frequency, machine cycle and instruction cycle.	05
2.	**PIC18F Programming Model and Instruction Set** PIC18 microcontroller programming model, Bus architecture, program memory and data memory organization, Special Function Registers (SFRs), General Purpose Registers (GPRs) *CPU registers:* Working Register (Wreg), Status Register, Bank Select Register (BSR), Instruction Decoder *Memory Pointers:* Program ROM and Program Counter (PC), Data ROM and Table Pointer (TBLPTR), File memory and File Select Register (FSR), Stack and Stack Pointer (STKPTR) *PIC 18 internal Architecture:* ALU, EEPROM, RAM, IO Ports, Timer, ADC, Serial port, CCP, Pipelining. (conceptual overview only) *Instructions and Assembly Programs:* Instruction Set, Instruction formats, Addressing modes, Assembler Directives, Assembly programs. (Assembly programs are restricted to basic arithmetic, logical and data transfer operations only)	08
3.	**PIC 18 Support Devices** *Timer Module:* Basic Concept of Timers and counters, Timer Registers, Control Registers, 8 bit and 16 bit operation (only for Timer 0), CCP module (Capture, Compare and PWM), Watch dog Timer. *ADC module:* ADC Features, Block diagram of ADC module, ADC Registers, ADCON0, ADCON1 and ADCON2. *Interrupt Module:* Basic concept of Interrupt, PIC 18 Interrupts, Interrupt versus polling, Interrupt sources, Interrupt vector, Interrupt service routine, Interrupt process, RCON, INTCON, IPR1 and PIE1.	06

4.	**Parallel Ports and Serial Communication** IO PORT Module: Basic concept of I/O interfacing, PORT Registers, TRIS Registers, LAT Registers, Simple input /output peripheral interfacing (switches & LEDs). Serial communication: Basics of serial communication, Data framing, USART module, SPBRG, TXREG, RCREG, TXSTA, RCSTA, PIR1	06
5.	**PIC Programming in C** *IO programming:* Byte size IO, Bit addressable IO. *Timer programming:* Generating delay, generating square wave. (for Timer0 using Interrupt based programming only) *Serial port programming:* Transmit data serially, Receive data serially. (Interrupt based programming only)	06
6.	**Microcontroller Applications** Interfacing matrix keyboard and Seven segments LED display, LCD Interfacing, ADC Interfacing, Traffic signal controller, DC motor interfacing, Stepper motor interfacing, PWM signal generation.	08

Text/Reference Books:-

1. Ramesh Gaonkar, "Fundamentals of Microcontrollers and Applications in Embedded Systems (with the PIC 18 Microcontroller Family)", Penram International publications (Ind) Pvt. Ltd.
2. Ali Mazidi, Rolind D Mckinlay and Danny Causey , "PIC Microcontroller and Embedded Systems", Pearson Education ltd., 2015
3. Robert B. Reese, "Microcontroller from Assembly Language to C using PIC18FXX2", Davinici Engineering press.
4. Han Way Huang, "PIC Microcontroller: An Introduction to Software and Hardware Interfacing", Cengage Learning, 2005.

Website Reference / Video Courses:

1. NPTEL Course: **Microprocessors And Microcontrollers** By Prof. Santanu Chattopadhyay, Dept. of Electrical Engineering, IIT Kharagpur:- Web link- https://nptel.ac.in/courses/108/105/108105102/

Assessment:

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

Theory Examination:

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

ELECTRICAL ENGINEERING SEM-VI						
Course code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEC603	Control System Design	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		3	--	3		3

Course Code	Course Name	Examination Scheme							
		Theory					Term Work	Pract/ Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEC603	Control System Design	20	20	20	80	3	-	-	100

Course Objectives	1. To establish a quantitative foundation to the design and analysis of Control systems. 2. To impart knowledge and skill on compensator design. 3. To study basics of digital control system and design of digital compensator. 4. To understand the concept of state –space analysis, to design the compensator in time and frequency domain, to design the PID compensator.
Course Outcomes	Upon successful completion of this course, the learner will be able to 1. Define fundamental control system design specifications and basic principles of controller design 2. Understand the basic design of various compensators. 3. Design compensators using root locus techniques. 4. Design modern controllers based on the state space techniques, 5. Recognize the importance of observability and controllability for system design.

Module	Contents	Hours
1.	Introduction to the Compensator: Basic concept of compensator design, its requirement, cascade compensator, feedback compensator, gain compensation, lag, lead and lag-lead compensator, proportional, derivative, integral Compensation, physical realization of compensator with passive and active components, basic block diagrams of a compensated closed loop control system.	03
2.	Design of Compensators using Root Locus Technique: Introduction, improving steady state error by gain compensation, transient response improvement by cascade compensation, improving steady state and transient response.	08
3.	Design of Compensators using Frequency Response Technique (Bode Plot): Introduction, Relation between closed-loop time response parameters of peak time, settling time, and percent overshoot with the open-loop frequency response parameters, transient response improvement by gain adjustment, Lag compensation, Lead compensation, Lag-lead compensation	08
4.	Design of Compensators using State variable approach: Introduction, pole placement topology, controller design by pole placement topology in phase variable form, controllability, controllability matrix, controllability by inspection, alternative approach to controller design, controller design by transformation. Introduction to Observer / estimator, observability, , observability matrix, observability by inspection, observer design by pole placement, alternative approach to Observer design. Steady state error design using integral control	07
5.	Digital control System: Introduction, advantage of digital control, components of digital control system, derivation of digital/ pulse transfer function, block diagram reduction, stability of digital system on Z-plane, bilinear transformation, steady state error and error constants	06
6.	Design of Digital Compensators:	07

	Transient response on the Z-plane, gain design on Z plane for transient response using root locus, stability design by root locus, cascade compensation (design of digital lead, lag and lag-lead compensator)of digital system using s-plane, implementing the digital compensator.	

Text Books:-

1. Control system engineering by Norman Nise 2nd edition
2. Digital Control Systems by Benjamin C. Kuo,Oxford series 2nd Edition
3. Control Engineering: An Introductory Course by Wilkie J., Johnson M., Katebi R., Palgrave MacMillan.
4. Industrial Control Electronics: Devices, Systems and Applications by Bartelt, Delmar Thomson Learning, 1st edition

Reference Books:-

1. Modern control Engineering by Richard C Dorf, SH Bishop, & Wesley edition, Eighth Edition
2. Linear Control system Analysis and design with MATLAB, by J.J. Azzo, C. H. Houpis, S.N. Sheldon, Marcel Dekkar, ISBN 0824740386
3. Control System Engineering, Shivanagraju s. Devi L., New age International latest edition
4. Control System engineering by Nagrath and Gopal, 5th to latest edition , Wiley Eastern
5. Modern control system engineering by K. Ogata, printice Hall.
6. Automatic control systems, Basic analysis and Design, William A. Wolovich, Oxford
7. Process Control principles and applications, Surekha Bharot, Oxford Higher education

Website Reference / Video Courses:

1. NPTEL Course: **Advanced Linear Continuous Control Systems** By Prof. Yogesh Hote, Dept. of Electrical Engineering, IIT Roorkee:- Web link- https://nptel.ac.in/courses/108/107/108107115/
2. NPTEL Course: Industrial Instrumentation By Prof. Prof. S. Mukhopadhyay and Prof. S.Sen, IIT Kharagpur:- Web link- https://nptel.ac.in/courses/108/105/108105062/

Assessment:

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

Theory Examination:

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

ELECTRICAL ENGINEERING SEM-VI						
Course Code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEC604	Signals and Systems	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		3	--	3		3

Course Code	Course Name	Examination Scheme							
		Theory					Term Work	Pract/ Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEC604	Signals and Systems	20	20	20	80	3	-	-	100

Course Objectives	1. To impart knowledge on continuous and discrete time signals. 2. To understand the basic properties of signals & systems 3. To know the methods of characterization of LTI systems in time domain 4. To analyze discrete time signals and system in the Fourier and Z transform domain 5. Understand the design of various types of digital filters and implement them using various implementation structures
Course Outcomes	Upon successful completion of this course, the learner will be able to 1. Discriminate continuous and discrete time signals and systems. 2. Understand the transformation of discrete time signal to Z domain. 3. Analyse frequency response of systems using Z domain. 4. Design, implementation, analysis and comparison of digital filters for processing of discrete time signals

Module	Contents	Hours
1.	Introduction- Classification of Signals and Systems: Definitions of signal and system. Standard signals- Step, Ramp, Pulse, impulse, Real and complex exponentials and Sinusoids, Classification of signals – Continuous time (CT) and Discrete Time (DT) signals, Periodic & Aperiodic signals, Deterministic & Random signals, Even and odd, Energy & Power signals, Classification of systems- Linear/ Non-Linear, Time-Variant/Invariant , Causal /Anti causal, stable/unstable, Memory/ Memory less System (static and dynamic), Sampling Theorem (Derivation is not Required). Basic operations on signals-Folding, Scaling and Time shifting). Convolution in DT domain (Matrix Method only)	07
2.	Z-Transform Z-Transform of bilateral signal, Definition of ROC, Properties of ROC, Properties of Z-transform, Inverse Z-Transform (only partial fraction).	05
3.	Frequency Response & Fourier Series Pole-zero plot in DT domain, Minimum phase, Maximum phase, Mixed phase and Linear, Phase System based on location of zeros, Low pass, high pass, Band pass and band reject system based on pass band frequency, Formation of Difference Equation, Solution of difference Equation (with & without initial Conditions), Zero input, zero state and Total Response of the system, Magnitude and phase response (only Analytical Method). , Introduction to Fourier Series: Representation of continuous time Periodic Signals, convergence of the Fourier Series, Properties of continuous time Fourier Series, Fourier Series representation of discrete time periodic signals, Properties of discrete time Fourier Series	10
4.	Discrete and Fast Fourier Transform DTFT, DFT & IDFT (Only Matrix Method), Properties of DFT, DIT FFT Algorithm (Radix-2)	06
5.	Design of FIR System	06

	Introduction to FIR System, Group Delay, phase Delay, Condition for Linear phase FIR system, Window Technique (only Rectangular window function, Hamming Window function)	
6.	Design of IIR System Introduction to IIR System & Bilinear Transformation, Digital Butterworth Filter design using Bilinear Transformation	05

Text Books:-

1. Salivahan S.," Digital Signal Processing", TMH Publication,2012
2. Oppenhein & Schafer," Discrete Time Signal Processing," PHI Publication 1989.
3. Haykin S and Van Veen B," Signal and System", Wiley Publication, 2nd Ed.
4. Linder D.K.," Introduction to Signal & System," McGraw Hill International, 1999.

Reference Books:-.

1. Proakis & Manolakis," Digital Signal Processing", PHI Publication, 1995.
2. Mitra S.K.," Digital Signal Processing," TMH Publication, 2001.
3. Digital Signal Processing: A Practitioner's Approach, Kaluri V. Rangarao, Ranjan K. Malli November 2006, John Wiley.
4. Li Tan,"Digital Signal Processing, Fundamental & Application", Elsevier Publisher, Academic Press
5. DSP – A Practical Approach – Emmanuel C. Ifeacher, Barrie. W. Jervis, 2 ed., Pearson Education

Website Reference / Video Courses:

1. NPTEL Course: Principles of Signals And Systems By Prof. Ravindra Arora, Dept. of Electrical Engineering, IIT Kanpur:- Web link- https://nptel.ac.in/courses/108/104/108104100/
2. NPTEL Course: Signals And Systems By Prof. Kushal K. Shah, Dept. of Electrical Engineering, IISER Bhopal :- Web link- https://nptel.ac.in/courses/108/106/108106163/

Assessment:

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

Theory Examination:

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

ELECTRICAL ENGINEERING SEM-VI						
Course code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEDO6011	Special Electrical Machines	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		3	--	3		3

Course code	Course Name	Examination Scheme							
		Theory					Term Work	Pract/ Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEDO6011	Special Electrical Machines	20	20	20	80	3	-	-	100

Course Objectives	• To impart knowledge on special electrical machines and its control
Course Outcomes	Upon successful completion of this course, the learner will be able: 1. To exemplify the working of Stepper motor and its control 2. To demonstrate the functioning of SRM motor and its control 3. To illustrate the working of BLDC motor and its control 4. To illustrate the operational features of PMSM motor and its control 5. To illustrate the operational features of Synchronous reluctance motor and its control 6. To illustrate the working of Linear motors

Module	Contents	Hours
1	Stepper motor and its Control: Features, construction, application and working of Stepper motor Characteristics – Open Loop and Closed Loop Control – Control Strategies -Power Converter Circuit –DSP/ Microcontroller based Control	07
2	Switched reluctance Motor and its Control: Features, construction, application and working of Switched Reluctance motor; Open Loop and Closed Loop Control- Control Strategies - Power Converter Circuit –DSP/ Microcontroller based Control – Sensor less control	07
3	Brushless DC Machines and its control: Brushless DC Machines Construction and working principle, Equivalent magnetic circuit, Type of converter and speed control, Comparison between the axial and radial permanent magnet motors, Applications. Characteristics – Open Loop and Closed Loop Control – Control Strategies - Power Converter Circuit –DSP/ Microcontroller based Control	07
4	Permanent Magnet Synchronous Machine and its control: Features, construction , application and working of PMSM, Characteristics – Open Loop and Closed Loop Control – Control Strategies - Power Converter Circuit –DSP/ Microcontroller based Control	07
5.	Synchronous Reluctance Motor and its control Construction, Working, Phasor Diagram, Torque Equation, Control - Direct Axis Current Control, Fast Torque Response Control, Advantages	06
6.	Linear Induction Machine Construction, Types, Working, Feature, Thrust Equation, Equivalent circuit, Characteristics, Control, Application	05

Books Recommended:

Text Books:

1. E. G. Janardanan — Special Electrical Machine PHI, publication
2. G. K. Dubey- Fundamentals of Electrical Drives, CRC press 2002 - Technology & Engineering
3. K. Venkataratnam- Special Electric Machines, Universities Press, Apr-2009 - Technology & Engineering

Reference Books:

1. D. C. Hanselman — Brushless Permanent-Magnet Motor Design—Eman Press LLC
2. R. Krishnan, SWITCHED RELUCTANCE MOTOR DRIVES Modeling, Simulation, Analysis, Design, and Applications, CRC Press.
3. M. Ramamoorty, O. Chandra Sekhar—Electrical Machines - PHI publication
4. R Krishnan — Permanent Magnet Synchronous and Brushless DC Motor Drives—CRC press

Website Reference / Video Courses:

1. NPTEL Course: **Advanced Electric Drives** By Dr. S.P. Das, Department of Electrical Engineering, IIT Kanpur:- Web link- https://nptel.ac.in/courses/108/104/108104011/
2. NPTEL Course: **Fundamentals of Electric Drives** By Dr. S.P. Das, Department of Electrical Engineering, IIT Kanpur:- Web link- https://nptel.ac.in/courses/108/104/108104140/

Assessment:

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

Theory Examination:

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

ELECTRICAL ENGINEERING SEM-VI						
Course Code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEDO6012	Electric Traction	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		3	--	3		3

Course code	Course Name	Examination Scheme							
		Theory					Term Work	Pract/ Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEDO6012	Electric Traction	20	20	20	80	3	-	-	100

Course Objectives	• To impart knowledge of principles of electrical traction • To explore various electrical subsystems of traction • To increase the awareness of latest developments in electric traction systems
Course Outcomes	Upon successful completion of this course, the learner will be able: 1. To illustrate the basics as well as the state of the art of electrical traction systems and subsystems. 2. To understand traction mechanics and different factors contributing to the traction. 3. To illustrate and analyse the performance of various traction motors and drives 4. To explain the traction power Supply arrangement and its protection aspects. 5. To understand the design requirements of the overhead equipments 6. To demonstrate the functioning of railway signaling system

Module	Contents	Hours
1	Introduction to Electric Traction: Requirements of Ideal Traction Systems, the Indian Scenario of Electric traction, Present day State of art Electric traction as a Viable Transport Strategy, Advantages of Electric Traction over other systems of traction, Ideal choice of traction system, Power supply systems for Electric Traction, DC systems, Single phase ac system and three phase ac systems, Kando systems, Latest Developments in 3phase with special reference to locomotives, EMUs and Metro stock, Role of Battery banks in Traction, types and maintenance.	04
2.	Traction Mechanics: Types of services, Speed-Time Curve, Trapezoidal, Quadrilateral Speed-Time Curve, Mechanics of train movement, Different Speed - time characteristics for train movement, Requirement of tractive effort and tractive effort produced, Train resistance, Power output and energy output from driving axles, Specific energy consumption & Factors affecting SEC, Adhesion & Coefficient of adhesion, Concept of Weight Transfer and weight transfer due to torque exerted by Traction motor, Influence of Electrical parts on Co-efficient of adhesion, wheel slip detection device (Numericals)	08
3.	Traction motor and Drives: Type of traction motor best suited for traction duties, Available motor characteristics and their suitability for traction duties, speed control methods, Braking methods, special Emphasis and techniques of regenerative braking, Optimization of design and construction features for improved power to weight ratio, Power Factor and Harmonics, Tractive Effort and Drive Ratings, Important Features of Traction Drives, conventional DC and AC Traction drives, Semiconductor/IGBT based Converter Controlled Drives, DC Traction using Chopper Controlled Drives, AC Traction employing Poly-phase motors, Traction control of DC locomotives and EMU's, Traction control system of AC locomotives, Control gear, PWM control of induction motors, Power & Auxiliary circuit equipment (Other than traction	10

	motors), Linear Induction motors, introduction to Maglev Technology.	
4.	**Power Supply Arrangement and Protection:** Traction substation, spacing and location of Traction substations, Major equipment at traction substation, selection and sizing of major equipment like transformer and Switchgear, Types of protection provided for Transformer and overhead lines, surge protection, maximum demand and load sharing between substations, sectionalizing paralleling post and feeder posts, Booster transformers, Return Conductor, 2X25KV AC system, controlling/monitoring, Railway SCADA systems, Train lighting and Air-conditioning	07
5.	**Overhead Equipment and Track circuits:** Design requirement of catenary wire, contact wire, Dropper, Height, span length, Automatic weight tensioning, section insulator, overlap, Different techniques of current collection (overhead and underground systems), neutral section, overhead crossing of power lines, Protection.	05
6.	**Railway Signaling:** Block Section Concept, AC/DC Track Circuits, Interlocking Principle, Train speed and signaling, Solid state Interlocking, Automatic Warning Systems, CAB signaling, Signaling level crossing. Permissible limit of EMI and EMC, Permissible capacitively-coupled current, Coupling between circuits, conductive coupling, Electrostatic induction.	05

Textbook and Reference Books

1. Modern Electric traction by H.Partab:
2. Electric Traction – Motive Power and Energie Supply by Andreas Steimel, Oldenbourg Industrieverlag GmbH, 2008
3. Electrical Railway Transportation Systems by Morris Brenna, Federica Foiadelli and Dario Zaninelli, IEEE Press and Wiley, 2018
4. Power Electronics and Electric Drives for Traction Applications Edited by Gonzalo Abad, Wiley, 2017

Assessment:

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

Theory Examination:

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

ELECTRICAL ENGINEERING SEM-VI						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credit Assigned		
		Theory	Practical	Theory	Practical	Total
EEDO6013	High Voltage Engineering	3	-	3		3

Course Code	Course Name	Examination Scheme							Total
		Theory				Practical			
		Internal Assessment			End Sem. Exam	Term work	Pract. & Oral	Oral	
		Test 1	Test 2	Avg					
EEDO6013	High Voltage Engineering	20	20	20	80	-	-	-	100

Course Objectives	1. To understand various breakdown processes in solid, liquid and gaseous insulating materials. 2. To impart the knowledge of Generation of high voltage DC, AC and Impulse voltages and currents. 3. To impart the knowledge of Testing and Measurement of high voltage DC, AC and Impulse voltages and currents. 4. To understand the design and layout of H V Laboratories
Course outcomes	Upon successful completion of this course, the learner will be able: 1. To know the fundamentals properties of the materials and their failure mechanisms to get appropriate and optimal design. 2. To explain and calculate the generation and measurement of High DC, AC and Impulse voltages and currents. 3. To understand testing of High voltage power apparatus. 4. To illustrate the major requirements in design of HV Laboratories.

Module	Contents	Hours
1	Electrostatic Fields, Their Control and Estimation: • Electric field Stress, its control and Estimation, Numerical methods – Finite difference, Finite Element and Charge simulation method for estimation of Electric Field. Surge voltage, their distribution and control	04
2	Conduction and Breakdown in Air and Other Gaseous Dielectrics: • Gases as insulating media, Collision Processes, Ionization process in gas, Townsend's Theory, current growth equation in presence of primary and secondary ionization processes, Townsend's criterion for breakdown in electronegative gases, Limitation of Townsend's theory, Panchen's law, Breakdown in non-uniform fields and corona discharges. • Streamer mechanism of breakdown, Post-breakdown phenomenon and application. • Practical considerations in using gas for insulation purposes. (Numerical on Townsend's theory and Paschen's law)	07
3	Breakdown in Liquid and Solid Dielectrics: • Liquid Dielectrics, Conduction and breakdown in pure liquids, Conduction and breakdown in commercial liquids: Suspended Particle Theory, Cavitations and bubble Theory. • Solid dielectrics used in practice, Intrinsic, Electro-mechanical and Thermal breakdown, Breakdown of solid dielectrics in practice, due to chemical, electrochemical deterioration, treeing, tracking, Internal discharges. • Breakdown of composite insulation, Application of insulating materials in electrical power apparatus, electronic equipment's.	06

4	**Generation & Measurement of High Voltage and Currents:** • Generation of high voltage and currents: Generation of high DC voltages by rectifier, Voltage doublers and multiplier circuits. • Electrostatic machines, Generation of high AC voltage – Cascading of transformers, series and parallel Resonance transformer (system), Tesla coil. • Generation of impulse voltages and currents-Impulse voltage definition, wave front and wave tail time, Multistage impulse generator, Modified Marx circuit, Tripping and control of conventional impulse generators, Introduction to Generation of high impulse current, (Design of Marx Generators circuits- numerical can be taken). • Generation of switching surges. (Numerical based on impulse generation, high DC voltage generation, optimum number of stages)	08
5	**Measurement of High Voltages and Currents:** • High ohmic series resistance with micro-ammeter., HVAC and impulse voltage-Resistance and capacitance voltage dividers, Sphere gap for measurement of High DC, AC and impulse voltages, Capacitance Voltage Transformer • Measurement of High DC, AC and impulse currents	06
6	**High Voltage Testing of Electrical Power Apparatus and H V Laboratories Layouts:** • Non-destructive testing of dielectric materials, DC resistivity measurement, Dielectric and loss factor measurement, Partial discharge measurement. • Testing of insulators and bushing, Power capacitors and cables testing, testing of surge diverters. • High Voltage laboratory–design, planning and layout. - Size and dimensions of the equipment and their layout, Classification of HV laboratory, Earthing and Shielding of H.V. laboratories, its importance.	08

Textbooks:

1. C. L. Wadhwa, “High Voltage Engineering”, New Age International Publishers Ltd.
2. M. S. Naidu, V. Kamaraju, “High Voltage Engineering”, Tata McGraw Hill Publication Co. Ltd. New Delhi

Reference books:

1. E. Kuffel, W. S. Zaengl, J. Kuffel, “High Voltage Engineering Fundamentals”, Newnes Publication
2. Prof. D. V. Razevig Translated from Russian by Dr. M. P. Chourasia, “High Voltage Engineering”, Khanna Publishers, New Delhi
3. Ravindra Arora, Wolf Gang Mosch, “High Voltage Insulation Engineering”, New Age International Publishers Ltd. Wiley Estern Ltd.
4. High Voltage Engineering Theory and Practice by M. Khalifa Marcel Dekker Inc. New York and Basel.
5. Subir Ray, “An Introduction to High Voltage Engineering” PHI Pvt. Ltd. New Delhi

Website Reference / Video Courses:

1. **NPTEL Course: High Voltage Engineering** By Prof. Aditya K. Jagannatham, Dept. of Electrical Engineering, IIT Kanpur:- Web link- **https://nptel.ac.in/courses/108/104/108104048/**

Assessment:

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Theory Examination:

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

ELECTRICAL ENGINEERING SEM-VI						
Course Code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEDO6014	Energy Storage	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		3	--	3		3

Course code	Course Name	Examination Scheme							
		Theory					Term Work	Pract/ Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEDO6014	Energy Storage	20	20	20	80	3	-	-	100

Course Objectives	• To explore the various energy storage technologies and their major applications • To increase awareness of ES suitability and capacity calculation for any given applications
Course Outcomes	Upon successful completion of this course, the learner will be able: 1. To illustrate the importance of energy storage systems in Power systems and other application domains 2. To illustrate the operational features of various energy storage technologies 3. To understand the principles and types of thermal, mechanical, electrochemical and electrical energy storage systems. 4. To compare and contrast different types of Energy storage systems 5. To illustrate the hybridization of various ES technology to improve the performance 6. To calculate the capacity of ES system for various application requirements,

Module	Contents	Hours
1.	Introduction to Energy Storage systems and components: Historical Perspective, Storage Needs, Variations in Energy Demand, Interruptions in Energy Supply, Demand for Portable Energy, Environmental and sustainability issues; Necessity of energy storage, different types of energy storage, mechanical, chemical, electrical, electrochemical, biological, magnetic, electromagnetic, thermal, comparison of energy storage technologies;	07
2.	Thermal Energy Storage: Principles and applications, Latent heat, sensible heat storage. Molten salt, Solar pond, seasonal thermal energy storage, Ice storage; Energy and exergy analysis of thermal energy storage.	05
3.	Mechanical Energy Storage: Potential Energy Storage, Energy Storage in Pressurized Gas, Compressed air energy storage (CAES), Flywheel, Applications	04
4.	Electrochemical Energy Storage: Parameters to be considered, Cyclic behaviour, equivalent circuit of electrochemical cell, self-discharge, Battery technologies: Flow battery, Rechargeable battery, Lead-acid, Nickel-Metal hydride, Lithium Ion; Battery system model, parameters; emerging trends in batteries. Fuel Cell: types, comparison and applications.	07
5.	Electrical Energy Storage: Pumped hydro storage system, Energy Storage in Capacitors, Comparative Magnitudes of Energy Storage, Transient behaviour of a Capacitor, Super-capacitor, series connection of super capacitors, charge balancing of super capacitors; Superconducting magnetic energy storage (SMES), Applications	06

6.	**Design, Sizing and Applications of Energy Storage**: Design considerations for sizing of different types of energy storage systems for various applications, case studies; Renewable energy storage- Battery sizing for stand-alone applications; Small scale application-Portable storage systems; (Numerical) E-mobility storage applications- Electric vehicles (EVs), batteries, super-capacitors and fuel cells, future technologies. Electric vehicle: V2X, G2V and V2G modes of operation. Hybrid Energy storage systems: configurations and applications. Energy Storage - Charging methodologies, SoC, SoH, SoS estimation techniques.	10

Textbook:

1. Robert Huggins, Fundamentals, Materials and Applications Second Edition, Springer, 2016
2. Dincer I., and Rosen M. A. (2011); Thermal Energy Storage: Systems and Applications,Wiley
3. Leo J.M.J. Blomen and Michael N. Mugerwa, "Fuel Cell System", New York, Plenum Press, 1993.
4. Ahmed Faheem Zobaa, Energy storage – Technologies and Applications, InTech Publication 2013.
5. Jiuchun Jiang and Caiping Zhang, Fundamentals and Applications of Lithium-Ion Batteries In Electric Drive Vehicles, Wiley, 2015
6. K.T. Chau, Energy Systems for Electric and Hybrid Vehicles, IET, UK, 2016
7. M. Broussely and G. Pistoia, Industrial Applications of Batteries From Cars to Aerospace and Energy Storage, Elsevier, 2007.

Reference books

1. S. Kalaiselvam and R. Parameshwaran , Thermal Energy Storage Technologies for Sustainability Systems Design, Academic Press, 2014
2. Trevor M. Letcher, Storing Energy with Special Reference to Renewable Energy Source, Elsevier, 2016.
3. Frank S. Barnes and Jonah G. Levine, Large Energy Storage Systems Handbook, CRC Press, 2011
4. Aiping Yu, Victor Chabot, and Jiujun Zhang, Electrochemical Super-capacitors For Energy Storage And Delivery Fundamentals And Applications, CRC Press, 2013.
5. Younghyun Kim and Naehyuck Chang, Design and Management of Energy-Efficient Hybrid Electrical Energy Storage Systems, Springer, 2014

Assessment:

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

Theory Examination:

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

ELECTRICAL ENGINEERING SEM-VI						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credit Assigned		
		Theory	Practical	Theory	Practical	Total
EEL601	Power System Protection And Switchgear Lab	-	2	-	1	1

Course Code	Course Name	Examination Scheme							Total
		Theory				TW/Practical/Oral			
		Internal Assessment			End Sem. Exam	Term work	Pract. & Oral	Oral	
		Test 1	Test 2	Avg					
EEL601	Power System Protection And Switchgear Lab	-	-	-	-	25	--	25	50

Course Objectives	• To introduce the concept of different protection schemes
Course Outcomes	Upon successful completion of this course, the learner will be able: 1. To understand the working principle of various protective devices like Circuit breakers, fuses, switches and contactors. 2. To understand the concept of various over current protection scheme and its applications in power system. 3. To understand different protection schemes of transformer and Induction motor. 4. To understand protection schemes of transmission line.

Syllabus: Same as that of Course EEC601-Power System Protection and Switchgear

Suggested List of Laboratory Experiments: Minimum six experiments need to be performed.

1. Demonstration of working parts of different Fuses and Contactor.
2. Demonstration of working parts of MCB, MCCB, RCCB & Circuit breakers.
3. To perform overcurrent protection using Induction Disc relay by setting different TSM and plot time vs current characteristics.
4. To perform overvoltage protection using Induction Disc relay by setting different TSM and plot time vs current characteristics.
5. Demonstration of different protection schemes like protection against overload, locked rotor, single phasing of 3 phase Induction motor.
6. Demonstration of differential protection of 3 phase transformer.
7. Demonstration of Directional Over-current protection relay.
8. To perform simulation of Numerical Based relay.
9. To perform simulation of distance protection in transmission line.

- Any other experiment based on syllabus, which will help students to understand topics/concept.
- It is desirable to arrange the Visit to a substation and a report preparation.

Industry Visit: Students' visit to be arranged to the nearby industry involved in design/ manufacturing/ processing in the following electrical engineering domains: Electrical Switchgears / Electrical Substation / Electrical Machines / Traction Locomotives / HV Equipments / Energy Storage . All students shall submit visit report in appropriate format as a part of the submission for EEL601.

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

Virtual Lab Website Reference

1. http://vlab.co.in/broad-area-electrical-engineering
2. http://vlab.co.in/broad-area-electronics-and-communications

Term work:

Term work shall consist of minimum six experiments. The distribution of marks shall be as follows:

Experiments Performance	: 10 marks
Journal	: 05 marks
Industrial Visit Report	: 05 Marks
Attendance (Theory and Practical)	: 05 marks

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

Oral Examination:

Oral examination will be based on entire syllabus of EEC601-Power System Protection and Switchgear

ELECTRICAL ENGINEERING SEM-VI						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credit Assigned		
		Theory	Practical	Theory	Practical	Total
EEL602	**Microcontroller Applications Lab**	**-**	**2**	**-**	**1**	**1**

Course Code	Course Name	Examination Scheme							Total
		Theory				Practical			
		Internal Assessment			End Sem. Exam	Term work	Pract. & Oral	Oral	
		Test 1	Test 2	Avg					
EEL602	**Microcontroller Applications Lab**	-	-	-	-	**25**	**25**	**-**	**50**

Course Objectives	1. To impart the Assembly language programming knowledge of PIC 18 microcontroller. 2. To impart the Embedded C programming knowledge of PIC 18 microcontroller
Course Outcomes	Upon successful completion of this course, the learner will be able to 1. To write, debug and execute Assembly language based programs. 2. To write, debug and execute embedded language based programs. 3. To design and implement the interfacing of internal peripheral devices. 4. To design and implement the interfacing of external peripheral devices.

Syllabus: Same as that of Course EEC602 Microcontroller Applications

Suggested List of Laboratory Experiments: Minimum four from Group (A) and four from Group (B), in all minimum eight experiments need to be performed.

(A) Assembly Language Programming:

1. To perform Addition, subtraction
2. To perform Multiplication and Division
3. To perform Logical operations (AND, OR, X-OR, NOT)
4. To sort Even and Odd numbers
5. To sort Negative and Positive numbers
6. To Find Largest Number
7. To Find Largest Number
8. To copy source array to destination array (Table related process)
9. To Toggle the bits of Port.

(B) Embedded C Language Programming:

1. Timer programming to Generate square wave
2. Timer programming to Generate time delay
3. Timer programming to Generate the PWM pattern
4. ADC programming to perform Analog to digital conversion
5. Serial communication programming for serial data transfer
6. IO port programming to interface simple switches and 7-segment LED Display
7. IO port programming to interface Liquid Crystal Display (LCD)
8. Stepper Motor interfacing
9. DC Motor interfacing
10. Traffic Signal programming

Any other experiment based on syllabus, which will help students to understand topics/concept.

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

Virtual Lab Website Reference

1. http://vlab.co.in/broad-area-electrical-engineering
2. http://vlab.co.in/broad-area-electronics-and-communications

Term work:

The term work shall consist of minimum 08 experiments based on PIC 18F microcontroller using assembly and embedded C language and minimum 02 assignments. The distribution of marks shall be as follows:

Experiments Performance	: 10 marks
Journal (Experiment and Assignments)	: 10 marks
Attendance (Theory and Practical)	: 05 marks

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

Practical & Oral Examination:

Practical & Oral examination will be based on entire syllabus of EEC602-Microcontroller Applications

ELECTRICAL ENGINEERING - SEMESTER-VI						
Course code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEL603	Control System Design Lab	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		--	2		1	1

Subject code	Subject Name	Examination Scheme							
		Theory					Term Work	Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEL603	Control Systems Design Lab	---	---	---	---	--	25	-	25

Course Objectives	1. To enable the students to strengthen their understanding of the design and analysis of control systems through practical exercises 2. Use of modern software tools to analyze and simulate the performance of realistic system models and to design control systems to satisfy various performance specifications.
Course Outcomes	Upon successful completion of this course, the learner will be able to 1. Implement various types of compensators and control algorithms using simulation platforms 2. Apply root-locus & Bode Plot techniques to analyze and design control systems. 3. Able to design digital controllers, assess their design through the constraint specifications

Syllabus: Same as EEC603: Control System Design

Suggested List of Laboratory Experiments: Minimum eight experiments need to be performed.

1. To draw the frequency response characteristic of a given lag- lead compensating network.
2. To study the effect of P, PI, PD and PID controller on step response of a feedback control system (Using control engineering trainer/process control simulator). Verify the same by simulation.
3. Design of a Lead compensator using Root-locus method
4. Design of a lag compensator using Root-locus method
5. Design of a lead-lag compensator using Root-locus method
6. Design of a lead compensator using bode plot method
7. Design of a lag compensator using bode plot method
8. Design of a lead-lag compensator using bode plot method
9. Obtain transfer function of a given system from state variable model and vice versa. State variable analysis of a physical system - obtain step response for the system by simulation
10. State variable analysis using simulation tools. To obtain step response and initial condition response for a single input, two output system in state variable form by simulation.
11. Familiarization with digital control system toolbox
12. Determination of z-transform, inverse z-transform & pole zero map of discrete systems to study step response of a discrete time system and effect of sampling time on system response
13. To explore the Properties of Digital Control Systems. Convert continuous time system to discrete system and vice versa. Root Locus of Digital control system on z-plane

Any other experiment based on syllabus which will help students to understand topic/ concept is also suggested.

Note: Students and teachers are encouraged to use the virtual labs whose links are as given below The remote-access to Labs in various disciplines of Science and Engineering is available. Students can conduct online

experiments which would help them in learning basic and advanced concepts through remote experimentation.

Virtual Lab Website Reference

1. http://vlab.co.in/broad-area-electrical-engineering
2. http://vlab.co.in/broad-area-electronics-and-communications

Term work:

Term work shall consist of minimum eight experiments. The distribution of marks shall be as follows:

Experiments Performance : 10 marks
Journal : 10 marks
Attendance (Theory and Practical) : 05 marks

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

ELECTRICAL ENGINEERING- SEM-VI						
Course Code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEL604	SBL-III: Industrial Automation Lab	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		-	4		2	2

Course Code	Course Name	Examination Scheme							
		Theory					Term Work	Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEL604	SBL-III: Industrial Automation Lab	--	--	--	--	--	25	25	50

Course Objectives	1. Develop necessary acquaintance with components and subsystems used in industrial automation 2. Develop the necessary skillset to integrate, monitor, maintain such systems
Course Outcomes	Upon successful completion of this course, the learner will be able: 1. To comprehend with various components and subsystems used in industrial automation 2. To understand the integration of components and sub-systems. 3. To interface the microcontroller / PLC with external devices/ sensors/ actuators. 4. To interface the microcontroller / PLC with control circuits. 5. To design /implement / integrate such systems for any given applications

Section A:

Lab contents shall be covered through some of the following ways:

1) Class room discussions / Expert Lectures
2) Visiting various industries involving such facilities to illustrate industrial automation
3) Multiple day webinar specifically organized to cover such contents
4) In-house facility for demonstration of Industrial automation
5) Hands-on Workshop
6) Exhibitions showcasing these technologies
7) Using virtual Instrumentation platform
8) Using Virtual Lab platform (Virtual Labs (vlab.co.in)

Contents:

1) Components and subsystems used in Industrial automation:

Controllers: Computers, Distributed Control Systems (DCS), Programmable Logic Controllers (PLC), Embedded Controllers.

Operator Interfaces (HMI)-Text based, Graphical, Touchscreens.

Sensors-Analog & Digital; Encoders, Proximity sensor, Ultrasonic Sensors, Photoelectric Sensors; Limit Switches

Actuators-Pneumatic, Hydraulic, Electric; Motors- AC, DC, Linear, Servo and Stepper motor.

Mechanisms and Machine Elements- Cam Driven Systems, ratchets and pawl, gears; Linkages and coupling; Conveyors- Belt, Roller, Chain, Vibrating, Pneumatic.

Motion Profile- trapezoidal velocity motion, S-curve velocity motion, Multi-axis motion

hardware and software platforms for Distributed Control System, DCS Functional Block Diagram, and Sequential Flow Charts

Software- Design and Analysis software, PLC programming, SCADA

2) Industry 4.0:

Conceptual Framework- Main Concepts and Components of Industry 4.0; Technology Roadmap for Industry 4.0; Technologies and Applications: Data Analytics in Manufacturing, Role of IoT, Robotics in the era of Industry 4.0, Additive Manufacturing, 3D printing; Augmented Reality

3) Real life Applications:
   a) Agriculture/ farm produce-sorting and grading system
   b) Automated / Robotic Assembly line
   c) Temperature Control in Process Industries
   d) Cyclic Operation of Traffic Lights
   e) Conveyor System for an Assortment of Objects
   f) Automatically filling of two tanks with liquid
   g) Automated warehouse management system
   h) Automated bottle filling plant
   i) Automated packaging system

4) Industrial Safety Practices:
   General Workplace Safety rules and procedures, recommended safety practices, Personal Protective Equipments (PPE), Industrial safety Acts and regulations

Section B:

Based on the insights received with the coverage of syllabus contents specified in section A, the students should carry out detailed study of at least six different applications listed below (maximum two from any group is desirable). They should have hands-on experience with each of these applications. Wherever possible software development / coding should be done by students.

Group 1: Pneumatic and Hydraulic based Industrial Automation systems:
   a) Electro-Pneumatic System for Pickup and Lay Down of Plastic Containers
   b) Design and assembly of Pneumatic / Hydraulic circuit and wiring of control interface for a particular application
   c) Application with different types of Pneumatic / Hydraulic valves and actuators
   (Any other application which incorporates Pneumatic and Hydraulic components)

Group 2: Drives and Control- Industrial Automation systems
   a) Linear Motion Control System
   b) PLC based Motion Control System
   c) VFD control of Motor
   d) HMI interface based Control
   e) Conveyor belt system
   f) Sorting and grading System for Agriculture Applications
   g) Home automation system with Web Server
   h) Lift control System (Demo)
   (Any other application which incorporates (Drives / Control)

Group 3: Use of IoT in following Applications
   a) Smart Agriculture,
   b) Smart City,
   c) Smart Life—Wearable Technologies,
   d) Smart Health
   e) Smart Grid
   (Any other application which incorporates IoT)

Group 4: Other Applications: Based on PLC/ Embedded micro-controller
   a) To wire up hardware, write and implement ladder programs for the following controls.
      i. Lamp control for various situations.
         a. Staircase control, hospital etc.
         b. Traffic light control.
      ii. Water level control using level sensors

iiii. Logic implementation for Bottle Filling Application

b) Tune PID controller for heat exchanger using DCS
(Any other suitable application)

Note: For each of the experiment carried out, students should prepare a detailed report, clearly specifying following:

[1] Technical description and specification of the system
[2] Drawing/ schematic/ block diagram for system visualization
[3] Components used and their specs
[4] Interconnectivity between the components
[5] Working principle
[6] Software tools used
[7] Program code (if any) developed
[8] Observations
[9] Photographs of the system

Books Recommended:

1. Industrial Automation Hands-On, by Frank Lamb, McGraw-Hill, 2013
2. Industrial Motion Control- Motor Selection, Drives, Controller Tuning, Applications, by Hakan Gürocak Wiley, 2016
3. Industry 4.0: Managing The Digital Transformation, by Alp Ustundag and Emre Cevikcan, Springer, 2018
4. Introduction to Industrial Automation, by Stamatios Manesis and George Nikolakopoulos, CRC Press, 2018

Term Work:

Term work shall consist of minimum requirement as given in the syllabus. The distribution of marks for term work shall be as follows:

Laboratory Performance : 15 marks
Journal : 05 marks
Attendance : 05 marks

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

Oral Examination:

Oral examination will be based on experiments carried out in EEL604-SBL-III- Industrial Automation Lab

ELECTRICAL ENGINEERING - SEMESTER-V						
Course Code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEM601	Mini Project – 2B	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		--	4$	--	2	2

Course Code	Course Name	Examination Scheme							
		Theory					Term Work	Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEM601	Mini Project – 2B	--	--	--	--	--	25	25	25

$ indicates work load of Learner (Not Faculty)

Course Objectives	1. To design and develop a moderately complex electrical/electronic/digital circuit with practical applications. 2. To understand basic concepts of circuit design while developing the project. 3. To enable the students to gain hands-on experience independently proposing and implementing the project and thus acquire the necessary confidence to deal with complex electrical/electronic/digital systems.
Course Outcomes	Upon successful completion of this course, the learner will be able to: 1. Identify problems based on societal /research needs. 2. Apply Knowledge and skill to solve societal problems in a group. 3. Develop interpersonal skills to work as member of a group or leader. 4. Draw the proper inferences from available results through theoretical/ experimental/ simulations. 5. Analyse the impact of solutions in societal and environmental context for sustainable development. 6. Use standard norms of engineering practices 7. Excel in written and oral communication. 8. Demonstrate capabilities of self-learning in a group, which leads to life-long learning. 9. Demonstrate project management principles during project work

A. Mini Project -Topic Selection and Approval

1. The group may be of maximum **FOUR (04)** students.
2. Students should propose project ideas & finalize the project idea in consultation with guide/ HOD. Students should select a problem which addresses some basic home, office or other real life applications. The mini project must have hardware part. The software part is optional.
3. Students should identify different components/ devices, instruments, simulation/emulations software tools required for the project.
4. Students should submit implementation plan in the form of Gantt/ PERT/ CPM chart, which will cover weekly activity of project.
5. A Log Book to be prepared by each group to record the work progress in terms of milestones per week by students. Weekly comment, remarks to be put by guiding faculty.

B. Mini Project –Execution

i. Design and Fabrication

a. Initial fabrication of the project by students can be done using standard devices/material/software tools to verify the circuit functionalities Initial project fabrication and testing is expected to be done by soldering/assembling on general purpose PCB/ Bakelite boards or suitable platforms required for the electrical/electronic/digital components. Discourage the use of breadboards.
b. If essential, use of a simulation/ emulation software tools to test and verify the performance of the circuit should be encouraged.
c. Students should prepare the proper drawings (electrical/ mechanical), schematics/ layouts of the project.
d. For final implementation of the circuit, preparation of PCB (if any required) using suitable CAD tools and fabricating the same in the lab is expected.

ii. Devices/ Components/ Systems to be Used:

Students are encouraged to use passive components like resistors, capacitors, inductors etc. If any specialize inductor is not readily available, the fabrication of the same in the lab should be encouraged. Other components like: Transistors, diodes, voltage regulators, logic gates, Op-amps, general purpose microcontroller, DC motors/ AC motors, sensors, actuators, relays etc. (Students may add more components as per the requirement of project).

iii. Testing and analysis of the Project

Students should test the circuit using suitable laboratory equipments like power supply, multi-meter, CRO, DSO etc. In case of any debugging requirement, students should record the problems faced during the testing and solutions sought after for the fault in the circuit.

All the testing results must be well documented in the final project report verifying the functionalities of the propose project.

iv. Use of Reference Material/Literature :

Students are advised to refer Application Notes, research publications & data sheets of various electrical/electronic/digital devices from Texas Instruments, Microchips, International Rectifiers, ST Microelectronics, Philips, NXP and many other manufacturers.

C. Project Report Format:

Mini Project **report** should include circuit diagram, operation, application, design details, testing, waveforms (if applicable) references, simulation results and final prepared PCB image, conclusion, etc. Project report should include report of all above steps listed in (2) and the conclusion.

Note:-

It is expected that the department should organise some of the guidance expert lectures / video lectures/ courses/ webinars/ workshops etc. for the students at the appropriate timing during the Mini Project practical slots on following topics:

1) Understanding passive components viz. resistors, capacitors and inductors from practical point of view: types/ varieties, device packages, applications and cost.
2) Understanding semiconductor components viz. diodes, BJT and JFET/MOSFETs from practical point of view: types/ varieties, device packages, applications and cost.
3) Design principles of simple electrical / electronic circuits with some examples.
4) Selection of switches and circuit protection components.
5) Selection and sizing of wires and conductors.
6) Soldering Practice.
7) Heat-sinking and Enclosure design concepts
8) Overall workmanship while working on the project fabrication.
9) Use of different software tools for design and development of circuits

11) Use of standard as well as some of the advanced laboratory equipments needed for testing of such projects

Application Domains:

List of key application domains from where students are encouraged to derive Mini Projects topics:

1) Smart Agriculture solutions
2) Power converter applications in various Applications
3) IoT based applications in power systems
4) AI/ML applications in disaster management
5) Renewable Energy
6) Energy Conservation
7) Energy Storage
8) Battery Charging and Protection
9) Fire Safety
10) Electrical System Protection
11) Lighting Control
12) Wireless Power Transfer
13) Electrical Components Testing
14) Electrical Parameters Measurement
15) Non-conventional Electricity Generation
16) Laboratory Equipments
17) E-Mobility / Electric Vehicles
18) Video Surveillance Systems
19) Robotics for Hazardous applications
20) Waste Management System
21) Smart City Solutions
22) Smart Classrooms and learning Solutions
23) Design of Electrical Equipment
24) PLC based automation system
25) Power system Monitoring System (EMS)

It is every much expected that the complexity of the Mini Project 2A/ 2B should be increased compared to the selection of projects during Mini Project 1A/1B. Also based on the subjects learned in Sem. III and Sem. IV the broader area inclusive of the concepts learned must be selected. Students can identify the mini project topics either from above suggested domains or any other relevant electrical engineering domains. The inter-disciplinary nature of the project is also desirable.

Guidelines for Assessment of Mini Project:

Term Work

- The review/ progress monitoring committee shall be constituted by head of departments of each institute. The progress of mini project to be evaluated on continuous basis, minimum two reviews in each semester.
- In continuous assessment focus shall also be on each individual student, assessment based on individual's contribution in group activity, their understanding and response to questions.
- Distribution of Term work marks for both semesters shall be as below;
  - Marks awarded by guide/supervisor based on log book : 10
  - Marks awarded by review committee : 10
  - Quality of Project report : 05

Review/progress monitoring committee may consider following points for assessment based on either one year or half year project as mentioned in general guidelines.

One-year Mini Project:

- In first semester entire theoretical solution shall be ready, including components/system selection and cost analysis. Two reviews will be conducted based on presentation given by students group.
  - First shall be for finalization of problem
  - Second shall be on finalization of proposed solution of problem.
- In second semester expected work shall be procurement of components /systems, building of working prototype, testing and validation of results based on work completed in an earlier semester.
  - First review is based on readiness of building working prototype to be conducted.
  - Second review shall be based on poster presentation cum demonstration of working model in last month of the said semester.

Half-year Mini Project:

- In this case in one semester students' group shall complete project in all aspects including,
  - Identification of need/problem
  - Proposed final solution
  - Procurement of components/systems
  - Building prototype and testing
- Two reviews will be conducted for continuous assessment,
  - First shall be for finalization of problem and proposed solution
  - Second shall be for implementation and testing of solution.

Assessment criteria of Mini Project.

Mini Project shall be assessed based on following criteria;

1. Quality of survey/ need identification
2. Clarity of Problem definition based on need.
3. Innovativeness in solutions
4. Feasibility of proposed problem solutions and selection of best solution
5. Cost effectiveness
6. Societal impact
7. Innovativeness
8. Cost effectiveness and Societal impact
9. Full functioning of working model as per stated requirements
10. Effective use of skill sets
11. Effective use of standard engineering norms
12. Contribution of an individual's as member or leader
13. Clarity in written and oral communication

- In one year, project, first semester evaluation may be based on first six criteria's and remaining may be used for second semester evaluation of performance of students in mini project.
- In case of half year project all criteria's in generic may be considered for evaluation of performance of students in mini project.

Guidelines for Assessment of Mini Project Oral Examination:

- Report should be prepared as per the guidelines issued by the University of Mumbai.
- Mini Project shall be assessed through a presentation and demonstration of working model by the student project group to a panel of Internal and External Examiners preferably from industry or research organizations having experience of more than five years approved by head of Institution.
- Students shall be motivated to publish a paper based on the work in Conferences/students competitions

Oral Examination: Mini Project shall be assessed during oral examination based on following points:

1. Quality of problem and Clarity
2. Innovativeness in solutions
3. Cost effectiveness and Societal impact
4. Full functioning of working model as per stated requirements
5. Effective use of skill sets

6. Effective use of standard engineering norms
7. Contribution of an individual's as member or leader
8. Clarity in written and oral communication

Reference Books:

1. P. Horowitz and W. Hill, "The Art of Electronics", 3rd Edition, Cambridge University Press, 2015
2. R. S. Khandpur, "Printed Circuit Board", McGraw-Hill Education; 1st edition, 2005.
3. Simon Monk, "Hacking Electronic: Learning Arduino and Raspberry Pi", McGraw-Hill Education TAB; 2 edition (September 28, 2017).
4. Matthew Scarpino, Designing Circuit Boards with EAGLE: Make High-Quality PCBs at Low Cost, 1st Edition Prentice Hall.
5. P. Horowitz and W. Hill, The Art of Electronics, 3 Edition, Cambridge University Press.
6. Archambeault and D. James, PCB Design for Real-World EMI Control, Springer Publications
7. Mitzner, Kraig, "Complete PCB design using OrCAD Capture and PCB", Elsevier, 2009
8. Peter Dalmaris, "Kicad Like a Pro", Tech exploration
9. Charles Platt, "Encyclopedia of Electronic Components – Vol-1: Power, electromagnetism, and discrete semiconductors. ", Maker Media, 2012
10. Charles Platt, "Encyclopedia of Electronic Components – Vol-2: Integrated circuits, light sources, sound sources, heat sources, and high frequency sources. ", Maker Media, 2015

Suggested Software tools:

1. LTspice:https://www.analog.com/en/design-center/design-tools-and-calculators/ltspice-simulator.html#
2. Eagle : https://www.autodesk.in/products/eagle/overview
3. OrCAD: https://www.orcad.com/
4. Multisim : https://www.multisim.com/
5. Webbench: http://www.ti.com/design-resources/design-tools-simulation/webench-power-designer.html
6. Tinkercad : https://www.tinkercad.com/
7. Raspbian OS: https://www.raspberrypi.org/downloads
8. Arduino IDE: https://www.arduino.cc/en/main/software

Online Repository:

1. https://www.electronicsforu.com
2. https://circuitdigest.com
3. https://www.electronicshub.org
4. Github

University of Mumbai
Bachelor of Electrical Engineering
(With effect from 2022-23)

Honours* in Electric Vehicles

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

*** To be offered as Honours for Major Disciplines as–**

1. Electrical Engineering

2. Mechanical Engineering

For any other Major Disciplines which is not mentioned above, it may be offered as Minor Degree.

Reference: https://www.aicte-india.org/sites/default/files/APH%202020_21.pdf (page 99-101)

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

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

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

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

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

Text Books:-

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

Reference Books:-

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

Website Reference / Video Courses:

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

Assessment:

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

Theory Examination:

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

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

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

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

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

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

Text/Reference Books:-

1. Fundamentals And Applications Of Lithium-Ion Batteries In Electric Drive Vehicles by Jiuchun Jiang and Caiping Zhang, Wiley, 2015
2. Battery Management Systems for Large Lithium-Ion Battery Packs, by Davide Andrea, Artech House Publication, 2010
3. Electric Vehicle Battery Systems by Sandeep Dhameja, Newens, 2002
4. Fundamentals And Applications Of Lithium-Ion Batteries In Electric by Jiuchun Jiang and Caiping Zhang, Wiley, 2015
5. Optimal Charging Control of Electric Vehicles in Smart Grids by Wanrong Tang and Ying Jun Zhang, Springer, 2017
6. Plug In Electric Vehicles in Smart Grids Charging Strategies Edited by Sumedha Rajakaruna, Farhad Shahnia and Arindam Ghosh, Springer 2015
7. Technologies and Applications for Smart Charging of Electric and Plug-in Hybrid Vehicles edited by Ottorino Veneri, Springer, 2017
8. Solar Powered Charging Infrastructure for Electric Vehicles A Sustainable Development Edited by Larry E. Erickson, Jessica Robinson, Gary Brase, and Jackson Cutsor, CRC Press, 2017
9. Energy Systems for Electric and Hybrid Vehicles Edited by K.T. Chau, IET, 2016
10. Handbook of Automotive Power Electronics and Motor Drive Edited by Ali Emadi, CRC Press, 2005

11. Electric And Hybrid Vehicles Power Sources, Models, Sustainability, Infrastructure And The Market by Gianfranco Pistoia, Elsevier, 2013
12. AC Motor Control and Electrical Vehicle Applications, Second Edition by Kwang Hee Nam CRC Press, 2019

Website Reference / Video Courses:

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

Assessment:

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

Theory Examination:

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