

# 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)

**UNIVERSITY OF MUMBAI**



**Syllabus for Approval**

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

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**  
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**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.

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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

## 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 <sup>\$</sup>	--	--	2	--	2
<b>Total</b>		<b>15</b>	<b>14</b>	<b>1</b>	<b>15</b>	<b>7</b>	<b>1</b>	<b>23</b>

### 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
<b>Total</b>		--	--	<b>100</b>	<b>400</b>	--	<b>175</b>	<b>100</b>	<b>775</b>

\$ 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.

<b>Course Objectives</b>	<p><b>The course is aimed:</b></p> <ol style="list-style-type: none"> <li>To study the line and contour integrals and expansion of complex valued function in a power series.</li> <li>To understand the basic techniques of statistics for data analysis, Machine learning and AI.</li> <li>To study the probability distributions and expectations.</li> <li>To acquaint with the concepts of vector spaces used in the field of machine learning and engineering problems.</li> <li>To familiarize with the concepts of Quadratic forms and Singular value decomposition.</li> <li>To learn the concepts of Calculus of Variations.</li> </ol>
<b>Course Outcomes</b>	<p><b>On successful completion of course learner/student will be able to:</b></p> <ol style="list-style-type: none"> <li>Use the concepts of Complex Integration for evaluating integrals, computing residues &amp; evaluate various contour integrals.</li> <li>Demonstrate the use of Correlation and Regression to the engineering problems in data science, machine learning and AI.</li> <li>Illustrate understanding of the concepts of probability and expectation for getting the spread of the data and distribution of probabilities.</li> <li>Apply the concept of vector spaces and orthogonalization process in Engineering Problems.</li> <li>Use the concept of Quadratic forms and Singular value decomposition in various Engineering applications.</li> <li>Find the extremals of the functional using the concept of Calculus of variation.</li> </ol>

Module	Detailed Contents	Hours.
<b>1</b>	<p><b>Module: Complex Integration:</b></p> <ol style="list-style-type: none"> <li>1.1 Line Integral, Cauchy's Integral theorem for simple connected and multiply connected regions (without proof), Cauchy's Integral formula (without proof).</li> <li>1.2 Taylor's and Laurent's series (without proof).</li> <li>1.3 Definition of Singularity, Zeroes, poles of <math>f(z)</math>, Residues, Cauchy's Residue Theorem (without proof).</li> </ol> <p><b>Self-learning Topics:</b> Application of Residue Theorem to evaluate real integrations, Z-Transform.</p>	<b>07</b>

2	<p><b>Module: Statistical Techniques:</b></p> <p>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.</p> <p><b>Self-learning Topics:</b> Covariance, fitting of exponential curve.</p>	06
3	<p><b>Module: Probability Distributions:</b></p> <p>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 &amp; normal distribution.</p> <p><b>Self-learning Topics:</b> Moments, Moment Generating Function, Applications of Probability Distributions in Engineering.</p>	07
4	<p><b>Module: Linear Algebra: Vector Spaces:</b></p> <p>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.</p> <p><b>Self-Learning Topics:</b> Linear combinations, linear Dependence and Independence, QR decomposition.</p>	06
5	<p><b>Module: Linear Algebra: Quadratic Forms:</b></p> <p>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.</p> <p><b>Self-learning Topics:</b> Orthogonal Transformations, Applications of Quadratic forms and SVD in Engineering.</p>	07
6	<p><b>Module: Calculus of Variations:</b></p> <p>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.</p> <p><b>Self-Learning Topics:-</b> Brachistochrone Problem, Variational Problem, Hamilton Principle, Principle of Least action, Several dependent variables.</p>	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

<b>Course Objectives</b>	<p><b>The course is aimed:</b></p> <ol style="list-style-type: none"> <li>To impart knowledge of performance and operation of an induction motor.</li> <li>To impart the knowledge of working principle, operations, performance and applications of single phase and three phase Transformers.</li> </ol>
<b>Course Outcomes</b>	<p><b>Upon successful completion of this course, the learner will be able to:</b></p> <ol style="list-style-type: none"> <li>Illustrate working principle and performance of single phase transformer under different operating conditions</li> <li>Understand working principle of autotransformer.</li> <li>Analyze various types of connections and performance of three phase transformer under various conditions.</li> <li>Demonstrate working principle and evaluate the performance of three phase induction motor under various operating conditions.</li> <li>Exemplify various starting methods and speed control of three phase induction motor.</li> </ol>

Module	Detailed Contents	Hours
1	<p><b>Single phase Transformer:</b></p> 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	<p><b>Autotransformer:</b></p> Working, Advantages of Autotransformer over two winding Transformer, Disadvantages, Isolation Transformer working and its applications.	02
3	<p><b>Three Phase Transformer:</b></p> 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	<p><b>Three Phase Induction Motor:</b></p> 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	<b>Starting and Speed control of Three Phase Induction Motor:</b> 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	<b>Single phase Induction Motor:</b> 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, Starting methods, Split phase starting- Resistance split phase, capacitor split phase, capacitor start and run, shaded pole starting, Applications of 1 $\phi$ 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](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

<b>Course Objectives</b>	<p><b>The course is aimed:</b></p> <ol style="list-style-type: none"> <li>To understand working of logic families and logic gates.</li> <li>To study the combinational and sequential logic circuits.</li> <li>To understand Analog to Digital and Digital to Analog conversions.</li> <li>To introduce ROM as Programmable Logic Device.</li> </ol>
<b>Course Outcomes</b>	<p><b>Upon successful completion of this course, the learner will be able to:</b></p> <ol style="list-style-type: none"> <li>Perform conversion of various number systems</li> <li>Understand working of logic families and logic gates.</li> <li>Design and implement combinational circuits.</li> <li>Design and implement sequential circuits.</li> <li>Understand the process of Analog to Digital conversion and Digital to Analog conversion.</li> <li>Illustrate the use of PLDs to implement the given logical problem.</li> </ol>

Module	Detailed Contents	Hours
1	<p><b>Fundamentals of Digital Systems and Logic families:</b></p> <p>Number formats: Binary, signed binary, Octal, hexadecimal, BCD and their basic math operations (addition and subtraction)</p> <p>Logic gates: Digital signals, digital circuits, AND, OR, NOT, NAND, NOR and Exclusive-OR operations, Boolean Algebra, Specifications of Digital IC</p> <p>Logic Families: TTL, CMOS logic families, Comparison of TTL and CMOS, Interfacing of TTL and CMOS, Tri-state logic</p>	07
2	<p><b>Combinational Digital Circuits:</b></p> <p>Design &amp; 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</p> <p>Binary Arithmetic circuits: Adder and Subtractor (Half and Full), Multiplier, 2 bit comparators, Multiplexer, de-multiplexer, decoder</p> <p>Designing code converter circuit: binary to gray, Gray to Binary, Multiplexer (ULM), De-multiplexers, BCD to 7 segment</p>	10
3	<p><b>Sequential Digital Circuits</b></p> <p>Comparison of combinational &amp; 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.</p>	06
4	<p><b>A/D and D/A Converters:</b></p> <p>Digital to Analog converter: Weighted resistor converter, R-2R ladder D/A converter, examples of D/A converter ICs.</p>	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	<b>Semiconductor Memories:</b> 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	<b>Programmable Logic Devices:</b> 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](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	<b>Power Electronic Devices and Circuits</b>	<b>03</b>	-	-	<b>03</b>	-	-	<b>03</b>

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						
<b>20</b>	<b>20</b>	<b>20</b>	<b>80</b>	<b>03 Hrs</b>	-	-	-	<b>100</b>

<b>Course Objectives</b>	<p><b>The course is aimed:</b></p> <ol style="list-style-type: none"> <li>To impart knowledge about various power semiconductor devices related to its characteristics, ratings, protection and facilitate selection of semiconductor devices for various applications.</li> <li>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.</li> <li>To keep abreast with the latest technologies and research going on in different domains related to power electronics.</li> </ol>
<b>Course Outcomes</b>	<p><b>Upon successful completion of this course, the learner will be able to:</b></p> <ol style="list-style-type: none"> <li>Understand the basic operation and characteristics of various semi controllable and fully controllable devices</li> <li>Analyse various single phase and three phase power converter circuits and understand their applications.</li> <li>Analyse dc to dc converter circuits and their applications.</li> <li>Identify and describe various auxiliary circuits and requirements in power electronics applications such as gate driver circuit, snubber circuits and heat sinks.</li> <li>Apply the basic concepts to select devices and converters for various applications</li> </ol>

Module	Detailed Content	Hours
1	<p><b>Thyristors:</b> 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.</p> <p><b>Self study topic:</b> Other devices of Thyristor family</p>	<b>07</b>
2	<p><b>Power semiconductor devices:</b> 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.</p>	<b>06</b>
3	<p><b>Controlled Rectifiers:</b> 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.</p>	<b>08</b>
4	<p><b>Inverter:</b> Classification based on source and power level, Single phase bridge Inverters (VSI), Performance parameters, Three phase VSI (120° and 180° conduction mode), Voltage</p>	<b>06</b>



	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	<b>DC to DC Converter:</b> 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	<b>Auxiliary Circuits:</b> 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](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

<b>Course Objectives</b>	<p><b>The course is aimed:</b></p> <ol style="list-style-type: none"> <li>To learn the history of electric hybrid electric vehicles (EV &amp; HEV) and emphasize the need and importance of EV-HEV for sustainable future.</li> <li>To study the fundamental concepts and principles of electric and hybrid electric vehicles drive train topologies</li> <li>To develop a thorough understanding of the key elements of EV/HEV: Electric Machines for Propulsion Applications and Energy Sources</li> <li>To model, analyze and design electric and hybrid electric vehicles drive train and to understand energy management strategies</li> </ol>
<b>Course outcomes</b>	<p><b>Upon successful completion of this course, the learner will be able to:</b></p> <ol style="list-style-type: none"> <li>Identify and describe the history and evolution of electric &amp; hybrid electric vehicles.</li> <li>Identify and describe the principles of various EV/HEVs drive train topologies.</li> <li>Select electric propulsion system components for EV/HEV drives for the desirable performance and control.</li> <li>Compare and evaluate various energy sources and energy storage components for EV/HEV.</li> <li>Model, analyze and design EV/HEV drive train with energy management strategies.</li> <li>Recognize the need to adapt and engage in operations EV/HEV for sustainable transportation system.</li> </ol>

Module	Detailed Contents	Hours
1	<p><b>Introduction:</b></p> <p>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</p>	04
2	<p><b>Drive-train Topologies:</b></p> <p>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.</p>	07
3	<p><b>DC and AC Machines for Propulsion Applications:</b></p> <p>Electric system components for EV/HEV, suitability of DC and AC machines for EV/HEV applications, AC and DC Motor drives.</p>	05
4	<p><b>Energy Sources for EV/HEV:</b></p> <p>Requirements of energy storage in EV/HEV: batteries, fuel cells, flywheels and ultra-capacitors as energy sources for EV/HEV, characteristics and comparison of</p>	10



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

**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 Williamson, *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

<b>Course Objectives</b>	<p><b>To impart the knowledge on :</b></p> <ol style="list-style-type: none"> <li>1. Construction, principle of operation, design, performance and applications of single and three phase Transformers</li> <li>2. Construction, principle of operation, design, performance and applications of single and three phase Induction Motors.</li> </ol>
<b>Course Outcomes</b>	<p><b>Upon successful completion of this course, the learner will be able to:</b></p> <ol style="list-style-type: none"> <li>1. Demonstrate the working principles and types of connections of 1<math>\phi</math> and 3<math>\phi</math> transformers.</li> <li>2. Analyze the performance of 3<math>\phi</math> transformer under various operating conditions.</li> <li>3. Evaluate the performance of 3<math>\phi</math> induction motor by carrying no load test, blocked rotor test and load test</li> <li>4. Illustrate the operation of various type of 3<math>\phi</math> induction motor starters.</li> <li>5. Illustrate different methods of speed control and braking of 3<math>\phi</math> induction motors.</li> </ol>

**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

<b>Course Objectives</b>	<p><b>The course is aimed:</b></p> <ol style="list-style-type: none"> <li>To introduce core programming basics and program design with functions using Python programming language.</li> <li>To study the use of procedural statements like assignments, conditional statements, loops and function calls.</li> <li>To learn the supported data structures like lists, dictionaries and tuples in Python.</li> <li>To describe the need for Object-oriented programming concepts in Python.</li> </ol>
<b>Course Outcomes</b>	<p><b>Upon successful completion of this course, the learner will be able to:</b></p> <ol style="list-style-type: none"> <li>Describe the numbers, Math functions, Strings, List, Tuples and Dictionaries in Python</li> <li>Express different Decision Making statements and Functions</li> <li>Illustrate the skill of object oriented programming in Python to develop applications in electrical engineering</li> <li>Understand different File handling operations</li> <li>Understand the design of GUI Applications in Python and evaluate different database operations</li> </ol>

**Prerequisite:** Basic Programming syntax of Java/C.

Module	Detailed Contents	Hours
1	<p><b>Basics of Python</b></p> <p><b>Theory:</b> Numbers in Python, Basic &amp; Built-in Math functions, Number Formats, Strings, Quotes, print () Function, Assigning Values to Names &amp; 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.</p> <p><b>Lab Experiment:</b> Write python programs to understand Expressions, Variables, Quotes, Basic Math operations, Strings: Basic String Operations &amp; String Methods, List, Tuples, Dictionaries, Arrays (<b>Minimum Two Programs</b> based on math operations, Strings and List/Tuples/ Dictionaries)</p>	05
2	<p><b>Decision Making and Functions:</b></p> <p><b>Theory:</b> 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 &amp; Setting Your Parameters, Calling Functions from within Other Functions, Functions Inside of Functions, Layers of Functions</p>	05

	<b>Lab Experiment:</b> Write python programs to understand different decision making statements and Functions. ( <b>Minimum Two Programs</b> based on Decision making, Looping Statements and Functions)	
3	<p><b>Object Oriented Programming using Python programming:</b></p> <p><b>Theory:</b> 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.</p> <p><b>Lab Experiment:</b> Write python programs to understand different Object oriented features in Python (<b>Minimum Two programs</b> based on a) Classes &amp; objects, b) Constructors, c) Inheritance &amp; Polymorphism, d) Exception handling.</p>	05
4	<p><b>Advanced Python Libraries:</b></p> <p><b>Introduction to Objects and Functions of</b></p> <ol style="list-style-type: none"> <li>Numpy - core library for scientific computing</li> <li>Pandas - fast, powerful, flexible and easy to use open source data analysis and manipulation tool</li> <li>Matplotlib - comprehensive library for creating static, animated, and interactive visualizations</li> <li>SciPy - ecosystem of open-source software for mathematics, science, and engineering</li> </ol> <p><b>Lab Experiment:</b> Write <b>Minimum Two programs</b> python programs to understand different functionalities exposed by each of the above libraries.</p>	07
5	<p><b>GUI Programming and Databases Theory:</b></p> <p><b>GUI Programming</b> - 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 &amp; Update operations on database</p> <p><b>Lab Experiment:</b> Students should be given demonstration of GUI designing and database operations.</p>	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, 4<sup>th</sup> Edition, 2009,
2. Mark Lutz, *Programming Python*, O Reily, 4<sup>th</sup> Edition, 2010
3. Tim Hall and J-P Stacey, *Python 3 for Absolute Beginners*, 2009.
4. Magnus Lie Hetland, *Beginning Python: From Novice to Professional*, 2<sup>nd</sup> 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	-	

<b>Course Objectives</b>	<p><b>The course is aimed:</b></p> <ol style="list-style-type: none"> <li>To introduce the basic building blocks and applications Digital logic devices.</li> <li>To illustrate the students to practical circuits based on the power electronics devices used in various applications.</li> </ol>
<b>Course Outcomes</b>	<p><b>Upon successful completion of this course, the learner will be able to</b></p> <ol style="list-style-type: none"> <li>Use various digital logic Gates, flip-flops and counters for various applications</li> <li>Build, design and analyse sequential / combinational circuits.</li> <li>Understand the operation various power electronics devices and circuits</li> <li>Use power converters for various real life applications</li> <li>Realize the implementation of digital interface with power electronics converters</li> </ol>

**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**

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

**Group B: EEC403-Power Electronics Devices and Circuits:**

- Study of I-V characteristics of Thyristors (SCR/Triac)
- Study of switching characteristics of Power BJT/ Power MOSFET/ IGBT
- Implementation of Single phase Half wave and Full wave rectifiers
- Study of single phase PWM rectifier
- Implementation and testing of SPWM VSI.
- Design of IGBT gate drivers circuit
- 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	<b>Skill Based Lab- II PCB Design and Fabrication Lab</b>	-	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

<b>Course Objectives</b>	<p><b>The course is aimed:</b></p> <ol style="list-style-type: none"> <li>To develop the skill set to work on real-life projects and its design.</li> <li>To develop the required skill set to design, develop and assemble the PCB using the CAD tools</li> </ol>
<b>Course Outcomes</b>	<p><b>Upon successful completion of this course, the learner will be able to:</b></p> <ol style="list-style-type: none"> <li>Understand types of PCBs and various tools used for PCB design.</li> <li>Identify various electrical/electronic components and their packages/ footprints.</li> <li>Illustrate the use of PCB CAD tools and their features for the practical designs.</li> <li>Design the schematic, board layout for simple, moderately complex and complex circuits.</li> <li>Fabricate and assemble the PCBs for simple and moderately complex circuits.</li> </ol>

Module	Detailed Contents	Hours
1	<p><b>Basics of PCB Designing:</b></p> <p>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.</p>	06
2	<p><b>Electrical/ Electronic Components and Packages:</b></p> <p>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</p> <p>Different PCB connectors, Terminals, Terminal Blocks; Inductor and Transformers: pulse, low and high frequency); Capacitors and resistors; High voltage devices, Protection elements</p> <p>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.</p>	06
3	<p><b>PCB Development Tools:</b></p> <p>Introduction to open source and commercial softwares like: Proteus, Altium, Eagle, OrCAD, KiCAD etc.</p> <p>Schematic preparation, Selection of Components from standard and special libraries, Components Footprints, net-list, creating new component footprints / library. Updating libraries</p>	06



4	<p><b>PCB Artwork Designing:</b>  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.</p>	10
5	<p><b>PCB Designing in Lab:</b>  <b>Students should prepare PCBs for at least three projects:</b></p> <ul style="list-style-type: none"> <li>• First project should be a simple circuit: Complete schematic, board layout (single-sided), PCB fabrication, component mounting and testing to be completed.</li> <li>• Second project should be a moderately complex circuit: Complete schematic, board layout (Single layer), PCB fabrication, component mounting and testing to be completed</li> <li>• Third project should be a complex circuit: Complete schematic and board layout (multi-layer) design, gerber files generation to be completed.</li> </ul> <p>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.</p> <p>Each Project can be carried out based on the following steps:</p> <p><b>PCB project:</b> Selection of circuit, components, components packages, manufacturer (make), generic components, symbols.</p> <p>(i) Selection of circuit: PCB design practice can be carried out for following circuits:</p> <ol style="list-style-type: none"> <li>1. Analog Electrical / Electronic Circuits</li> <li>2. Linear DC Power Supply</li> <li>3. Op-amp based Signal Processing circuits</li> <li>4. Different measurement based on transducers /sensors.</li> <li>5. Mini Project based on Electrical / Electronic domain</li> <li>6. Microcontroller circuits etc.</li> </ol> <p>(ii) Components selection: Students can design/ select the components from datasheets/ manufacturer catalogues / data-book, online supplier's inventory etc.</p> <p>(iii) Selection of PCB type: PCB material, number of layers, thickness of copper etc.</p> <p>(iv) Prepare the schematic and board layout using the open source CAD tools or Licensed CAD tool available in the lab.</p> <p>(v) Fabricate PCB in the lab using printing, etching and drilling process.(Only two projects)</p> <p>(vi) Post PCB fabrication process: component mounting, soldering and Hardware Testing.</p> <p>(vii) Prepare the report on overall lab work carried out with schematics, PCB artwork final PCB fabrication and assembled PCBs photographs.</p>	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*, 1<sup>st</sup> 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
<b>EEM401</b>	<b>Mini Project – 1B</b>	-	<b>04<sup>s</sup></b>	-	-	<b>02</b>	-	<b>02</b>

\$ 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						
-	-	-	-	-	<b>25</b>	-	<b>25</b>	<b>50</b>

<b>Course Objectives</b>	<p><b>The course is aimed:</b></p> <ol style="list-style-type: none"> <li>To acquaint with the process of identifying the needs and converting it into the problem.</li> <li>To familiarize the process of solving the problem in a group.</li> <li>To acquaint with the process of applying basic engineering fundamentals to attempt solutions to the problems.</li> <li>To inculcate the process of self-learning and research.</li> </ol>
<b>Course Outcomes</b>	<p><b>Upon successful completion of this course, the learner will be able to:</b></p> <ol style="list-style-type: none"> <li>Identify problems based on societal /research needs.</li> <li>Apply Knowledge and skill to solve societal problems in a group.</li> <li>Develop interpersonal skills to work as member of a group or leader.</li> <li>Draw the proper inferences from available results through theoretical/experimental/simulations.</li> <li>Analyse the impact of solutions in societal and environmental context for sustainable development.</li> <li>Use standard norms of engineering practices</li> <li>Excel in written and oral communication.</li> <li>Demonstrate capabilities of self-learning in a group, which leads to life long learning.</li> <li>Demonstrate project management principles during project work.</li> </ol>

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

<ul style="list-style-type: none"> <li>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.</li> <li>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.</li> <li>Students shall submit implementation plan in the form of Gantt/PERT/CPM chart, which will cover weekly activity of mini project.</li> <li>A log book to be prepared by each group, wherein group can record weekly work progress, guide/supervisor can verify and record notes/comments.</li> <li>Faculty supervisor may give inputs to students during mini project activity; however, focus shall be on self-learning.</li> <li>Students in a group shall understand problem effectively, propose multiple solution and select best possible solution in consultation with guide/ supervisor.</li> <li>Students shall convert the best solution into working model using various components of their domain areas and demonstrate.</li> <li>The solution to be validated with proper justification and report to be compiled in standard format of University of Mumbai.</li> </ul>
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- 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", 3<sup>rd</sup> 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.**

### 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.

## (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

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