UNIVERSITY OF MUMBAI
No. UG/ 41 of 2018-19

CIRCULAR:-

Attention of the Principals of the affiliated Colleges and Directors of the recognized Institutions in Science & Technology Faculty is invited to this office Circular No. UG/179 of 2017-18, dated 8th August, 2017 relating to syllabus of the Bachelor of Engineering (B.E.) degree course.

They are hereby informed that the recommendations made by the Board of Studies in Electrical Engineering at its meeting held on 9th April, 2018 have been accepted by the Academic Council at its meeting held on 5th May, 2018 **vide** item No. 4.52 and that in accordance therewith, the revised syllabus as per the (CBCS) for the T.E. & B.E. in Electrical Engineering (Sem - V to VIII) has been brought into force with effect from the academic year 2018-19 and 2019-2020, accordingly. (The same is available on the University's website www.mu.ac.in).

(Dr. Dinesh Kamble)
I/c REGISTRAR

MUMBAI – 400 032
25th June, 2018

To

The Principals of the affiliated Colleges & Directors of the recognized Institutions in Science & Technology Faculty. (Circular No. UG/334 of 2017-18 dated 9th January, 2018.)

A.C/4.52/05/05/2018

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No. UG/ 41 -A of 2018 MUMBAI-400 032 25th June, 2018

Copy forwarded with Compliments for information to:-

1) The I/c Dean, Faculty of Science & Technology,
2) The Chairman, Board of Studies in Electrical Engineering,
3) The Director, Board of Examinations and Evaluation,
4) The Director, Board of Students Development,
5) The Co-Ordinator, University Computerization Centre,

(Dr. Dinesh Kamble)
I/c REGISTRAR

AC
Item No.

UNIVERSITY OF MUMBAI

Revised syllabus (Rev- 2016) from Academic Year 2016 -17

Under

FACULTY OF TECHNOLOGY

Electrical Engineering

Third Year with Effect from **AY 2018-19**

As per **Choice Based Credit and Grading System** with effect from the AY 2016–17

Program Structure for
TE Electrical Engineering
University of Mumbai
(With Effect from 2018-19)

Scheme for Semester V

Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Practical	Tutorial	Theory	Practical	Tutorial	Total
EEC501	Power System - II	4	-	1	4	-	1	5
EEC502	Electrical Machines - III	4	-	-	4	-	-	4
EEC503	Control System - I	4	-	-	4	-	-	4
EEC504	Power Electronics	4	-	-	4	-	-	4
EEDLO501X	Department Level Optional Course-I	3	-	1	3	-	1	4
EEL501	Business Communication and Ethics	-	4**	-	-	2	-	2
EEL502	Control System Lab	-	2	-	-	1	-	1
EEL503	Electrical Machines Lab - III	-	2	-	-	1	-	1
EEL504	Power Electronics Lab	-	2	-	-	1	-	1
Total		**19**	**10**	**2**	**19**	**5**	**2**	**26**

**** Out of four hours, 2 hours theory shall be taught to entire class and 2 hours practical in batches**

Examination Scheme for Semester V

Course Code	Course Name	Examination Scheme												Total Marks
		Theory				Term Work		Practical		Oral		Pract./Oral		
		External (UA)		Internal (CA)										
		Max Marks	Min Marks	Max Marks	Min Marks	Max Marks	Min Marks	Max Marks	Min Marks	Max Marks	Min Marks	Max Marks	Min Marks	
EEC501	Power System - II	80	32	20	8	25	10	-	-	-	-	-	-	125
EEC502	Electrical Machines - III	80	32	20	8	-	-	-	-	-	-	-	-	100
EEC503	Control System - I	80	32	20	8	-	-	-	-	-	-	-	-	100
EEC504	Power Electronics	80	32	20	8	-	-	-	-	-	-	-	-	100
EEDLO 501X	Department Level Optional Course-I	80	32	20	8	25	10	-	-	-	-	-	-	125
EEL501	Business Communication and Ethics	-	-	-	-	50	20	-	-	-	-	-	-	50
EEL502	Control System Lab	-	-	-	-	25	10	-	-	25	10	-	-	50
EEL503	Electrical Machines Lab - III	-	-	-	-	25	10	-	-	-	-	25	10	50
EEL504	Power Electronics Lab	-	-	-	-	25	10	-	-	-	-	25	10	50
Total		**400**	**-**	**100**	**-**	**175**	**-**	**-**	**-**	**25**	**-**	**50**	**-**	**750**

Program Structure for
TE Electrical Engineering
University of Mumbai
(With Effect from 2018-19)

Scheme for Semester VI

Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Practical	Tutorial	Theory	Practical	Tutorial	Total
EEC601	Protection and Switchgear Engineering	3	-	-	3	-	-	3
EEC602	Electrical Machines - IV	4	-	-	4	-	-	4
EEC603	Signal processing	3	-	1	3	-	1	4
EEC604	Microcontroller and its Applications	4	-	-	4	-	-	4
EEC605	Control System - II	4	-	-	4	-	-	4
EEDLO602X	Department Level Optional Course-II	3	-	1	3	-	1	4
EEL601	Electrical Protection Lab	-	2	-	-	1	-	1
EEL602	Electrical Machines Lab - IV	-	2	-	-	1	-	1
EEL603	Microcontroller Lab	-	2	-	-	1	-	1
EEL604	Simulation Lab – II	-	2	-	-	1	-	1
Total		**21**	**8**	**2**	**21**	**4**	**2**	**27**

Examination Scheme for Semester VI

Course Code	Course Name	Examination Scheme												Total Marks
		Theory				Term Work		Practical		Oral		Pract./Oral		
		External (UA)		Internal (CA)										
		Max Marks	Min Marks	Max Marks	Min Marks	Max Marks	Min Marks	Max Marks	Min Marks	Max Marks	Min Marks	Max Marks	Min Marks	
EEC601	Protection and Switchgear Engineering	80	32	20	8	-	-	-	-	-	-	-	-	100
EEC602	Electrical Machines - IV	80	32	20	8	-	-	-	-	-	-	-	-	100
EEC603	Signal processing	80	32	20	8	25	10	-	-	-	-	-	-	125
EEC604	Microcontroller and its Applications	80	32	20	8	-	-	-	-	-	-	-	-	100
EEC605	Control System - II	80	32	20	8	-	-	-	-	-	-	-	-	100
EEDLO602X	Department Level Optional Course-II	80	32	20	8	25	10	-	-	-	-	-	-	125
EEL601	Electrical Protection Lab	-	-	-	-	25	10	-	-	25	10	-	-	50
EEL602	Electrical Machines Lab - IV	-	-	-	-	25	10	-	-	-	-	25	10	50
EEL603	Microcontroller Lab	-	-	-	-	25	10	-	-	-	-	25	10	50
EEL604	Simulation Lab – II	-	-	-	-	25	10	-	-	25	10	-	-	50
Total		**480**	**-**	**120**	**-**	**150**	**-**	**-**	**-**	**50**	**-**	**50**	**-**	**850**

List of Department Level Optional Courses

Course Code	Department Level Optional Course - I
EEDLO5011	Communication Engineering
EEDLO5012	Renewable Energy and Energy Storage
EEDLO5013	Utilization of Electrical Energy

Course Code	Department Level Optional Course - II
EEDLO6021	Digital Communication Engineering
EEDLO6022	Micro-grid
EEDLO6023	Advanced Power Electronics

University of Mumbai						
Course Code	**Course Name**	**Teaching Scheme (Contact Hours)**		**Credits Assigned**		
		Theory	**Tutorial**	**Theory**	**Tutorial**	**Total**
EEC501	**Power System-II (abbreviated as PS-II)**	**4**	**1**	**4**	**1**	**5**

Course code	Course Name	Examination Scheme						
		Theory					Term Work	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)		
		Test 1	Test 2	Avg.				
EEC501	Power System –II	20	20	20	80	03	25	125

Course Objectives	• To impart knowledge on transmission line operation during fault. • To study power system transients and insulation co-ordination.
Course Outcomes	Student will be able • To understand different kind of faults on transmission line. • To analyse symmetrical fault • To analyse symmetrical components and unsymmetrical faults. • To illustrate and analyse power system transients • To understand insulation co-ordination in power system. • To understand and analyse corona on transmission line.

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 on Z bus formulation up to 3x3 matrix).**	14
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.	07
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, bus impedance matrix method for analysis of shunt type unsymmetrical faults. Analysis of series type unsymmetrical faults: one open conductor faults, two open conductor fault.	07
4	**Power System Transients**: Review of transients in simple circuits, recovery transient due to removal of short circuit, arcing grounds, capacitance switching, current	12

	chopping phenomenon. Travelling waves on transmission lines, wave equation, reflection and refraction of waves, typical cases of line terminations, attenuation, Bewely lattice diagram. 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.	
5	**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.	03
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, corona pulses- their generation and properties in EHV lines, charge voltage (q-v) diagram and corona loss.	05

Books Recommended:

Text Books*:*

1. Wadhwa C.L. *Electrical power system*, New Age International,4th edition,2005
2. HadiSaadat, Power System Analysis, TMH publications,2002
3. D. P. Kothari, I. J. Nagrath, Modern *Power System Analysis*,McGraw Hill,3rd edition,2006
4. B.R. Gupta, *Power System Analysis And Design*, S.Chand,4th edition,2007
5. Begamudre R.D. "Extra High Voltage AC Transmission Engineering", New Age International, 2nd edition
6. Soni M.L., Bhatanagar U.S, Gupta P.V, A *course in electrical power*, DhnapatRai sons
7. Timothy J.E.Miller, "Reactive Power Control in Electric Systems" Wiley India Pvt Ltd. 2010.
8. J.B.Gupta, "Course in power system" kataria Publication

Reference Books:

1. Stevenson, *Modern power system analysis*, TMH publication
2. TuranGonen, Modern power system analysis, Wiley,1988
3. Mehta V.K., *Principle of power system*, S Chand,4th edition,2005.
4. Arthur R. Bergen, Vijay Vittal, "Power System Analysis", Pearson Publication, Second Edition.

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

Term work:
Term work shall consist of minimum eight tutorials and assignments (minimum 2). The distribution of marks for term work shall be as follows:

Tutorials	:15 marks
Assignments	:05 marks
Attendance (Theory and Tutorial)	:05 marks

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

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

University of Mumbai						
Course Code	**Course Name**	**Teaching Scheme (Contact Hours)**		**Credits Assigned**		
		Theory	**Tutorial**	**Theory**	**Tutorial**	**Total**
EEC502	**Electrical Machines -III (abbreviated as EMC-III)**	**4**	**-**	**4**	**-**	**4**

Course code	Course Name	Examination Scheme						
		Theory					Term Work	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)		
		Test 1	Test 2	Avg.				
EEC502	Electrical Machines –III	20	20	20	80	03	-	100

Course Objectives	• To impart knowledge on performance and operation of an induction motor. • To study design aspects of an induction motor.
Course Outcomes	Student will be able • To illustrate the working principle of three phase induction motor • To analyse and evaluate performance of three phase induction motors under various operating conditions • To illustrate various speed control and starting methods of three phase induction motor. • To illustrate the working principle of single phase induction motor • To analyse the performance of single phase induction motor. • To design three phase induction motor

Module	Contents	Hours
1	**Three Phase Induction Motors:** Introduction, Construction, Principle of operation, Rotor emf & frequency, Current and Power, Power stages, phasor diagram, Analysis of Equivalent circuit, Torque-speed characteristics in braking, motoring and generating regions. Effect of voltage and frequency variations on Induction motor performance, Losses and efficiency, No load and block rotor test, Circle diagram, Applications of 3Φ IM, Relevant standards	12
2	**Three Phase Induction Motors: Speed Control and Starting:** Speed control methods including V/f method (excluding Slip power recovery scheme), Starting methods, High torque motors, Cogging and crawling.	06
3	**Single phase Induction Motor**: Introduction**,** Principle of operation, Double field revolving theory, Equivalent circuit of single phase induction motor, Determination of equivalent circuit parameters from no load and blocked rotor test.	04
4	**Types of Single phase Induction Motor & its Applications:** Staring methods, Split phase starting- Resistance spilt phase, capacitor split phase, capacitor start and run, shaded pole starting, Reluctance starting. Applications.	04
5	**Design of Three phase Induction motors:** Output equation, Choice of	12

	specific electric and magnetic loadings, Standard frames, Main dimensions, Design of stator and rotor windings, Stator and rotor slots, Design of stator core, air gap, Design of squirrel cage rotor, end rings, Design of wound rotor.	
6	**Performance Measurement of Three Phase Induction Motors:** Calculation of leakage reactance for parallel sided slot, Carter"s coefficients, Concept of B_{60}, Calculation of No load current, Short circuit current, Dispersion coefficient. Relevant standards	10

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
4. A.K. Sawhney, "*Electrical Machine Design*", Dhanpat Rai & Co
5. M.V.Deshpande, "*Design and Testing of Electrical Machines*", PHI Learning

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
4.K.G. Upadhyay, "*Design of Electrical Machines* ", New age publication

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

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

University of Mumbai						
Course Code	**Course Name**	**Teaching Scheme (Contact Hours)**		**Credits Assigned**		
		Theory	**Tutorial**	**Theory**	**Tutorial**	**Total**
EEC503	**Control System -I (abbreviated as CS-I)**	**4**	**-**	**4**	**-**	**4**

Course code	Course Name	Examination Scheme						
		Theory					Term Work	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)		
		Test 1	Test 2	Avg.				
EEC503	Control System –I	20	20	20	80	03	-	100

Course Objectives	• To impart knowledge on control system and modeling of system and its analysis.
Course Outcomes	Student will be able • To model electrical and electromechanical system using transfer function. • To Illustrate methodology for simplification of system • To model and analyse given system in state space • To analyse steady state condition of given system • To analyse the transient and stability conditions of physical system

Module	Contents	Hours
1	**Introduction to control system** Introduction, open loop and closed loop control system with examples, brief idea of multi variable control system.	02
2	**Mathematical Model of Physical System** Transfer function of electrical, mechanical (translational and rotational) and electro mechanical systems. 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 SFGand vice versa.	10
3	**Time domain Analysis** Time response analysis of first and second order systems, Under damped second order system with step input. System response with additional poles and zeros. Steady state error for unity feedback systems. Static error constants and system type. Concept of stability, absolute and relative stability using Routh Hurwitz criteria,	10
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	10
5	**Root locus techniques** Definition and properties of root locus, rules for plotting root locus,	05

	stability analysis using root locus, Transient response design via gain adjustment.	
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. Relationship between Closed loop transient, Closed and open loop frequency responses. Steady state error characteristics from frequency responses.	11

Books Recommended:

Text Books:

1. Control system engineering by Norman Nise 2nd to latest edition
2. Control System engineering by Nagrath and Gopal, 5th to latest edition , Wiley Eastern
3. Modern control system engineering by K. Ogata, printice Hal
4. Modern control Systems, Twelfth edition, by Richard C Dorf, Robert H Bishop, Pearson.

Reference Books:

1. Linear Control system Analysis and design with MATLAB, by J.J. Azzo, C. H. Houpis, S.N. Sheldon, Marcel Dekkar, ISBN 0824740386
2. Feedback control of Dynamic System, G.F. Franklin, Pearson higher education, ISBN 0130980412
3. Control System Engineering, Shivanagraju s. Devi L., New age International latest edition .
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

Assessment:

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

Theory Examination:

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

University of Mumbai						
Course Code	**Course Name**	**Teaching Scheme (Contact Hours)**		**Credits Assigned**		
		Theory	**Tutorial**	**Theory**	**Tutorial**	**Total**
EEC504	**Power Electronics (abbreviated as PE)**	**4**	**-**	**4**	**-**	**4**

Course code	Course Name	Examination Scheme						
		Theory					Term Work	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)		
		Test 1	Test 2	Avg.				
EEC504	Power Electronics	20	20	02	80	03	-	100

Course Objectives	• To impart knowledge about various power semiconductor devices related to its characteristics, ratings, protection and to select semiconductor devices for various applications. • To introduce different methods of power conversion such as ac to dc, dc to dc, dc to ac the underlying principles of converter operation and hence to analyze different converter circuits for power conversion. • To keep abreast with the latest technologies and research going on in different areas related to power electronics.
Course Outcomes	Student will be able to • Select and design power electronic converter topologies for a broad range of energy conversion applications. • Analyse and simulate the performance of power electronic conversion systems. • Analyse various single phase and three phase power converter circuits and understand their applications. • Apply the basic concepts of power electronics to design the circuits in the fields of AC and DC drives, power generation and transmission and energy conversion, industrial applications. • Identify and describe various auxiliary circuits and requirements in power electronics applications such as Gate driver circuit, and snubber circuits along with electrical isolation and heat sinks

Module	Contents	Hours
1	**Thyristors:** Basic operation of silicon controlled rectifier, two transistor analogy, Static and Dynamic characteristics, Gate characteristics, Firing circuits, Commutation circuits, Protection circuit of SCR, Basic operation and characteristic of Triac, GTO, Diac.	04
2	**Power semiconductor devices:** Basic operation and characteristics of power diodes, power BJTs, power MOSFETs, IGBTs, Silicon Carbide (SiC)and GaN devices, Safe Operation Area (SOA) for each devices. Comparison of devices, selection of devices for various applications, conduction and switching losses; Gate Drive Circuitry for Power Converters and snubber circuits, heat sinks.	12
3	**Controlled Rectifiers:** Single phase half wave rectifiers, full wave rectifiers (mid-point and bridge configuration) for R and R-L load,	08

	freewheel diode, harmonic analysis of input current and input power factor for single phase fully controlled rectifier, effect of source inductance (concept only), single phase dual converter, Three phase semi converter and full converter with R load, Applications, Numerical for calculation of output voltage, single phase PWM rectifier, basic working principle and applications.	
4	**Inverter:** Principle of operation, Performance parameters, Single phase voltage source bridge Inverters, Three phase VSI (120° and 180° conduction mode), control of inverter output voltage , PWM techniques-Single PWM, Multiple PWM, Sinusoidal PWM, Introduction to Space vector modulation, Current source inverters, comparison of VSI and CSI, Applications.	06
5	**DC to DC Converter**: Basic principle of dc to dc conversion, switching mode regulators – Buck, Boost, Buck-Boost, Cuk regulators, bidirectional dc to dc converters, all with resistive load and only CCM mode, Applications: Power Factor Correction Circuits, LED lamp driver, Numerical included.	08
6	**AC voltage controllers:** On-Off and phase control, Single phase AC voltage controllers with R and RL loads. **Cyclo converters, Matrix converter:** Basic working principle.	10

Books Recommended:

Text Books:

1. "Power Electronics" M.H.Rashid, Prentice-Hall of India
2. "Power Electronics", Ned Mohan, Undeland, Robbins, John Wiley Publication
3. "Power Electronics", P.C Sen, Tata McGrawhill
4. "Power Electronics: Devices, Circuits and Matlab Simulations" by Alok Jain, Penram International
5. "Power Electronics", V.R Moorthi, Oxford University press
6. "Thyristors & their applications", Ramamurthy
7. "Power Electronics", M.D Singh and Khanchandani, Tata McGrawhill
8. " Silicon Carbide Power Devices" B. Jayant Baliga

Reference Books:

1. "Power Electronics", Landers, McGraw Hill
2. "Power Electronics", P.S Bhimbra, Khanna Publishers
3. "Elements of power electronics" Philip T Krein, Oxford University Press
4. "Power Electronics for Technology", Ashfaq Ahmed, Pearson
5. "Power Electronics", Joseph Vithayathil, Tata McGrawhill
6. "Silicon Carbide, Volume 2: Power Devices and Sensors," Peter Friedrichs , Tsunenobu Kimoto, Lothar Ley and Gerhard Pensl , Wiley Publications
7. "Power Electronics Converters and Regulators," Dokić, Branko L. and Blanuša, Branko

Website Reference:

1. http://nptel.iitm.ac.in: 'Power Electronics' web-course

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

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

University of Mumbai						
Course Code	**Course Name**	**Teaching Scheme (Contact Hours)**		**Credits Assigned**		
		Theory	**Tutorial**	**Theory**	**Tutorial**	**Total**
EEDLO 5011	**Communication Engineering (abbreviated as CE)**	**3**	**1**	**3**	**1**	**4**

Course code	Course Name	Examination Scheme						
		Theory					Term Work	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)		
		Test 1	Test 2	Avg.				
EEDLO 5011	Communication Engineering	20	20	20	80	03	25	125

Course Objectives	• To impart knowledge on various modulation techniques in communication engineering. • To study different sampling techniques used in communication engineering.
Course Outcomes	Student will be able • To understand basic communication system and its components. • To illustrate and analyse amplitude modulation and demodulation techniques. • To illustrate and analyse phase modulation and demodulation techniques. • To illustrate and analyse frequency modulation and demodulation techniques. • To illustrate and analyse pulse modulation and demodulation techniques. • To understand and analyse radio receivers and sampling techniques.

Module	Contents	Hours
1	**Basics of Communication System** Types of signals, Block diagram, electromagnetic spectrum, signal bandwidth and power, types of communication channels, types of noise, signal to noise ratio, noise figure, and noise temperature	04
2	**Amplitude Modulation and Demodulation** Basic concept, signal representation, need for modulation, Spectrum, waveforms, modulation index, bandwidth, voltage distribution, and power calculation **DSBFC**: Principles, modulating circuits, low level and high level transmitters **DSB suppressed carrier**:- Multiplier modulator, nonlinear modulator, and switching Modulator, **Single Side Band (SSB):-**Principle, filter method, phase shift method and third method, independent sideband (ISB) and Vestigial Side Band (VSB) principles and transmitters **Amplitude demodulation:** Diode detector, practical diode detector, and square law Detector.	08
3	**Angle Modulation and Demodulation** **Frequency Modulation (FM):** Basic concept, mathematical analysis,	08

	frequency spectrum of FM wave, sensitivity, phase deviation and modulation index, frequency deviation and percent modulated waves, bandwidth requirement of angle modulated waves, deviation ratio, narrow band FM, and wide band FM. Varactor diode modulator, FET reactance modulator. Direct FM transmitter, indirect FM Transmitter, noise triangle in FM, pre-emphasis and de-emphasis. **Phase Modulation (PM): P**rinciple and working of transistor direct PM modulator, relationship and comparison between FM and PM. **FM demodulation:** Balance slope detector, Foster-Seely discriminator, ratio detector, comparison between FM demodulators, comparison between AM, FM and PM. Applications of FM and PM	
4	**Radio Receivers** TRF, Super-heterodyne receiver, receiver parameters, and choice of IF. AM receiver circuits and analysis, simple AGC, delayed AGC, forward AGC, and communication receiver, FM receiver circuits, comparison with AM receiver	06
5	**Pulse Modulation and Demodulation** PAM, PWM, PPM waveform generation and detection, principle, generation and detection of delta modulation and adaptive delta modulation. Applications of pulse communication	06
6	**Sampling Techniques** Theorem for low pass and band pass signals, proof with spectrum, Nyquist criteria, sampling techniques, aliasing error and aperture effect	04

Books Recommended:

Text Books:

1. Tomasi W. , "Advanced Electronics Communication systems", PGI, 4th Edition1998
2. Taub & Schiling, "Principles of Communication Systems", McGraw Hill, 2nd Ed. 1987
3. John C. proakis, "Digital Communication", McGraw Hill International, 1995
4. Haykin S, John Wiley & Sons, "Digital Communication", 3rd Ed. 1995

Reference Books:

1. Lathi B.P., "Modern Digital and Analog Communication System, Oxford University Press, 3rd Edition 1998
2. Dennis Roddy and John Coolen, "Electronic Communications", Prentice Hall of India, 3rd Ed. 1992

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

Term work:

Term work shall consist of minimum eight tutorials and assignments (minimum 2). The distribution of marks for term work shall be as follows:

Tutorials :15 marks
Assignments :05 marks
Attendance (Theory and Tutorial) :05 marks

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

Theory Examination:

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

University of Mumbai						
Course Code	**Course Name**	**Teaching Scheme (Contact Hours)**		**Credits Assigned**		
		Theory	**Tutorial**	**Theory**	**Tutorial**	**Total**
EEDLO 5012	**Renewable Energy and Energy Storage (abbreviated as REES)**	**3**	**1**	**3**	**1**	**4**

Course code	Course Name	Examination Scheme						
		Theory					Term Work	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)		
		Test 1	Test 2	Avg.				
EEDLO 5012	Renewable Energy and Energy Storage	20	20	20	80	03	25	125

Course Objectives	• To introduce the new paradigm of power generation in the form of renewable energy and the various means used for power processing and optimization. • To relate and study the various energy storage technology and their significance in the context of renewable energy based applications.
Course Outcomes	Student will be able to • Identify and describe the issues related to use of fossil fuels and to recognize means of mitigation through adaption of renewable energy (RE). • Identify and analyze the process of power generation through solar thermal and solar photovoltaic technologies. • Identify and describe the various components and types of Wind Energy system Fuel cell technology, tidal, wave, and biomass systems. • Identify and describe the importance of various forms of energy storage (ES) in new power generation scenario based on renewable energy. • Analyze, formulate and propose the power sharing mechanisms and to evaluate the fault scenarios in hybrid RE and ES sources. • Recognize the need to adapt and engage in operations RE/ES related activities for sustainable future.

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. Distributed generation, Future trends in power generation and distribution.	03
2	**Solar Energy- Solar Thermal applications-**Review of solar thermal applications-solar thermal conversion devices and storage 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	12

	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 Review of regulatory standards for solar PV installations, net-metering.	
3	**Wind Energy** Review of wind energy system and its components, types of wind turbines, characteristics; 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.	04
4	**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.	03
5	**Other Sources**- Review of other nonconventional sources, their features and applications; Biomass, Tidal, Ocean Thermal Electric Conversion, geothermal, and Micro-hydro.	04
6	**Energy Storage** Forms of energy storage, importance of storage system in new power generation scenario; Types, characteristics and performance evaluation of: batteries, ultra-capacitors, flywheels, SME, pumped hydro storage system; Applications of Energy storage in distributed generation, smart grid systems, Electric and Hybrid electric vehicles. Hybrid power system based on renewable energy and energy storage.	10

Books Recommended:

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. Robert Huggins, Energy Storage, Springer, 2010
11. M. Ehsani, Y. Gao, and Ali Emadi, *Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design*, Second Edition, CRC Press.

12. S. Chakraborty, M. G. Simões and W. E. Kramer, *Power Electronics for Renewable and Distributed Energy System*, Springer 2013
13. Ahmed Faheem Zobaa, *Energy storage – Technologies and Applications*, InTech Publication 2013.
14. 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:

1. http://nptel.iitm.ac.in: 'Energy Resources and Technology' web-course
2. http://nptel.iitm.ac.in: 'Non conventional Energy Systems' web-course

Other References Material

1. Heinrich Ha¨Berlin, *Photovoltaics System Design And Practice*, Wiley, 2012
2. Shin'ya Obara, *Design of Renewable Energy Systems: Microgrid and Nature Grid Methods*, Engineering Science Reference, 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

Term work:

Term work shall consist of minimum eight tutorials and assignments (minimum 2). The distribution of marks for term work shall be as follows:

Tutorials :15 marks
Assignments :05 marks
Attendance (Theory and Tutorial) :05 marks

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

Theory Examination:

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

University of Mumbai						
Course Code	**Course Name**	**Teaching Scheme (Contact Hours)**		**Credits Assigned**		
		Theory	**Tutorial**	**Theory**	**Tutorial**	**Total**
EEDLO 5013	**Utilization of Electrical Energy (abbreviated as UEE)**	**3**	**1**	**3**	**1**	**4**

Course code	Course Name	Examination Scheme						
		Theory					Term Work	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)		
		Test 1	Test 2	Avg.				
EEDLO 5013	Utilization of Electrical Energy	20	20	20	80	03	25	125

Course Objectives	• To impart the knowledge on different types of drives used in electric traction. • To impart the basic knowledge of some domestic electric appliances.
Course Outcomes	Students will be able • To understand and analyse the power factor for improving the quality of supply. • To analyse different type of traction systems. • To understand modern tools to control electric traction motors. • To understand concept of electrical heating and welding and their application. • To understand different methods of cooling systems used in domestic electric appliances.

Module	Contents	Hours
1	**Power Factor** Power factor, disadvantages of low power factor, Causes of low power factor, methods of power factor improvement, advantages of power factor improvement and economics of power factor improvement.	04
2	**Electric Traction** Requirement of an ideal traction system. Traction system- Non electric traction system, electric traction system, diesel traction. System of Track electrification- DC system, single phase, three phase, composite system (Kando system), single phase AC to DC system. Different accessories for track electrification- overhead wire, conductor rail system, current collector- pantograph, catenary. Traction mechanics-Types of services, speed time curve, trapezoidal and quadrilateral speed time curves, power and energy output from driving axles, average and schedule speed (numerical), specific energy consumption, factors affecting specific energy consumption, dead weight, accelerating weight and adhesive weight.	12
3	**Electric Traction Motors and Controls** Desirable characteristics of traction motors, suitability of DC series motors, AC series motors, three phase induction motors and linear	10

	induction motor for traction. Control of Traction motors- Requirement, starting and speed control by using rheostat control, series parallel method, transition from series to parallel (shunt transition, bridge transition), thyristor control method, chopper control of motor in DC Traction System, PWM control of induction motor. Breaking- Requirement of breaking system, mechanical breaking, electrical breaking, rheostatic breaking, regenerative breaking. Substation- Location and distribution system, substation equipment, traction SCADA and railway signaling.	
4	**Electric Heating** Classification of electric heating methods, Resistance heating- Direct resistance heating, indirect resistance heating, application, Arc heating- Direct arc heating, indirect arc heating, applications of arc heating, Induction heating. Core type induction furnaces- Ajax Wyatt furnace, coreless induction furnace, Application of induction heating. Dielectric heating- principle, choice of frequency for dielectric heating, application of dielectric heating. Eddy current heating principle and applications.	03
5	**Electric Welding** Electric welding- welding methods, electric arc welding, resistance types welding and application, modern welding techniques. Electric arc welding- Formation and characteristics of electric arc, effect of arc length, arc blow, Electrode used in arc welding, spot welding machine.	03
6	**Other application of Electrical Energy** Terminology, Refrigeration and Air conditioning, Refrigeration cycle, Vapour compression type, vapour absorption type, Electrical circuit of a Refrigerator, Room Air conditioner window type and split type.	04

Books Recommended:

Text Books:

1. Utilization of Electric Energy by J. B. Gupta, SK Kataria & Sons.
2. Utilization of Electric Energy by R. K. Rajput, Laxmi Publications (P) Ltd.
3. Generation, Distribution and Utilization of Electric Energy by C.L.Wadhwa, Wiley Eastern Ltd.
4. I. Hussein, *Electric and Hybrid Vehicles: Design Fundamentals*, CRC Press, 2003

Reference Books:

1. Art, Science of . Utilization of Electric Energy by H. Pratap, Dhanpat Rai & Sons
2. Electric Traction by H. Pratap, Dhanpat Rai & Sons
3. Designing with light- A Lighting Handbook by Anil Valia, Lighting System
4. Generation and Utilization of Electric Energy by S. Sivanagaraju, Pearson Eduction India
5. M. Ehsani, Y. Gao,S.E.Gay and Ali Emadi, *Modern Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design,* CRC Press. 2005
6. "Lamps and lighting" by M.A.Cayless, J.R.Coaton and A.M.Marsden

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

Term work:

Term work shall consist of minimum eight tutorials and assignments (minimum 2). The distribution of marks for term work shall be as follows:

Tutorials :15 marks
Assignments :05 marks
Attendance (Theory and Tutorial) :05 marks

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

Theory Examination:

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

University of Mumbai						
Course Code	**Course Name**	**Teaching Scheme (Contact Hours)**		**Credits Assigned**		
		Theory	**Practical**	**Theory**	**Practical**	**Total**
EEL501	**Business Communication and Ethics (abbreviated as BCE)**	**-**	**4****	**-**	**2**	**2**

Course Code	Course Name	Examination Scheme							Total
		Theory				Practical			
		Internal Assessment			End Sem. Exam	Term Work	Pract. and Oral	Oral	
		Test 1	Test 2	Avg.					
EEL501	Business Communication and Ethics	-	-	-	-	50	-	-	50

Course Objectives	• To inculcate professional and ethical attitude at the workplace • To enhance effective communication and interpersonal skills • To build multidisciplinary approach towards all life tasks • To hone analytical and logical skills for problem-solving
Course Outcomes	The students will be able to • Design a technical document using precise language, suitable vocabulary and apt style. • Develop the life skills/ interpersonal skills to progress professionally by building stronger relationships. • Demonstrate awareness of contemporary issues knowledge of professional and ethical responsibilities. • Apply the traits of a suitable candidate for a job/higher education, upon being trained in the techniques of holding a group discussion, facing interviews and writing resume/SOP. • Deliver formal presentations effectively implementing the verbal and non-verbal skills.

Module	Contents	Hours
01	**Report Writing**	05
1.1	Objectives of Report Writing	
1.2	Language and Style in a report	
1.3	Types : Informative and Interpretative (Analytical, Survey and Feasibility)and Formats of reports (Memo, Letter, Short and Long Report)	
02	**Technical Writing**	03
2.1	Technical Paper Writing (IEEE Format)	

2.2	Proposal Writing	
03	**Introduction to Interpersonal Skills**	08
3.1	Emotional Intelligence	
3.2	Leadership and Motivation	
3.3	Team Building	
3.4	Assertiveness	
3.5	Conflict Resolution and Negotiation Skills	
3.6	Time Management	
3.7	Decision Making	
04	**Meetings and Documentation**	02
4.1	Strategies for conducting effective meetings	
4.2	Notice, Agenda and Minutes of a meeting	
4.3	Business meeting etiquettes	
05	**Introduction to Corporate Ethics**	02
5.1	Professional and work ethics (responsible use of social media - Facebook, WA, Twitter etc.)	
5.2	Introduction to Intellectual Property Rights	
5.4	Ethical codes of conduct in business and corporate activities (Personal ethics, conflicting values, choosing a moral response and making ethical decisions)	
06	**Employment Skills**	06
6.1	Group Discussion	
6.2	Resume Writing	
6.3	Interview Skills	
6.4	Presentation Skills	
6.5	Statement of Purpose	

Books Recommended:

1. Fred Luthans, *"Organizational Behavior",* McGraw Hill, edition
2. Lesiker and Petit, *"Report Writing for Business",* McGraw Hill, edition
3. Huckin and Olsen, *"Technical Writing and Professional Communication",* McGraw Hill

4. Wallace and Masters, *"Personal Development for Life and Work",* Thomson Learning, 12th edition
5. Heta Murphy*, "Effective Business Communication",* Mc Graw Hill, edition
6. Sharma R.C. and Krishna Mohan, *"Business Correspondence and Report Writing",* Tata McGraw-Hill Education
7. Ghosh, B. N., *"Managing Soft Skills for Personality Development",* Tata McGraw Hill. Lehman,
8. Dufrene, Sinha, "BCOM", Cengage Learning, 2nd edition
9. Bell, Smith, "Management Communication" Wiley India Edition, 3rd edition.
10. Dr. Alex, K., "Soft Skills", S Chand and Company
11Subramaniam, R., "Professional Ethics" Oxford University Press.
12. Robbins Stephens P., "Organizational Behavior", Pearson Education
13. https://grad.ucla.edu/asis/agep/advsopstem.pdf

Suggested List of Assignments:

1. Report Writing (Theory)
2. Technical Proposal
3. Technical Paper Writing (Paraphrasing a published IEEE Technical Paper)
4. Interpersonal Skills (Group activities and Role plays)
5. Interpersonal Skills (Documentation in the form of soft copy or hard copy)
6. Meetings and Documentation (Notice, Agenda, Minutes of Mock Meetings)
7. Corporate ethics (Case studies, Role plays)
8. Writing Resume and Statement of Purpose

Term work:

Term work shall consist of all assignments from the list. The distribution of marks for term work shall be as follows:

Book Report:	10 Marks
Assignments:	10 Marks
Project Report Presentation:	15 Marks
Group Discussion:	10 Marks
Attendance:	05 Marks

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

University of Mumbai						
Course Code	**Course Name**	**Teaching Scheme (Contact Hours)**		**Credits Assigned**		
		Theory	**Practical**	**Theory**	**Practical**	**Total**
EEL502	**Control System Lab (abbreviated as CS Lab)**	**-**	**2**	**-**	**1**	**1**

Course Code	Course Name	Examination Scheme							Total
		Theory				Practical			
		Internal Assessment			End Sem. Exam	Term Work	Pract. and Oral	Oral	
		Test 1	Test 2	Avg.					
EEL502	Control System Lab	-	-	-	-	25	-	25	50

Course Objectives	• To study basic concepts of control system • To impart knowledge on various components of control systems.
Course Outcomes	Students will be able • To illustrate the functioning of various components of control system. • To analyse the response of physical system for various inputs. • To analyse the stability of the system using time domain and frequency domain techniques by simulation.

Syllabus: Same as that of Course EEC503 Control System – I

Suggested List of Laboratory Experiment:

(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

1. Draw root locus and hence obtain steady state stability of control system
2. Draw Bode plot and hence obtain steady state stability of control system
3. Draw Nyquist plot and hence obtain steady state stability of control system

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

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.

University of Mumbai						
Course Code	**Course Name**	**Teaching Scheme (Contact Hours)**		**Credits Assigned**		
		Theory	**Practical**	**Theory**	**Practical**	**Total**
EEL503	**Electrical Machines Lab - III (abbreviated as EMC Lab -III)**	**-**	**2**	**-**	**1**	**1**

Course Code	Course Name	Examination Scheme							Total
		Theory				Practical			
		Internal Assessment			End Sem. Exam	Term Work	Pract. and Oral	Oral	
		Test 1	Test 2	Avg.					
EEL503	Electrical Machines Lab –III	-	-	-	-	25	25	-	50

Course Objectives	• To impart practical knowledge of single phase and three phase induction motor.
Course Outcomes	Students will be able • To evaluate performance of single phase and three phase induction motor by carrying load test. • To analyse performance of single phase and three phase induction motor by carrying no load and blocked rotor test. • To illustrate the operation of various type of starters. • To illustrate different methods of speed control for three phase induction motor.

Syllabus: Same as that of Course EEC502 Electrical Machines - III

Suggested List of Laboratory Experiment:

1) Load Test on three phase sq. cage Induction Motor.
2) Load test on three phase slip ring induction motor.
3) No load and Blocked rotor test on three phase Induction Motor.
4) Performance analysis of three phase Induction Motor using Circle diagram.
5) Load Test on single phase Induction Motor.
6) No load and Blocked rotor test on single phase Induction Motor.
7) Study of different types of starters.
8) Speed control by v/f method.

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

Term work:

Term work shall consist of minimum six experiments, minimum two drawing sheets (full imperial size) or software based drawing of individual parts and the assembled views of three phase induction motor. Design should be based on the Indian Standard Specifications. 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.

Practical/Oral Examination:
Practical/Oral examination will be based on entire syllabus.

University of Mumbai						
Course Code	**Course Name**	**Teaching Scheme (Contact Hours)**		**Credits Assigned**		
		Theory	**Practical**	**Theory**	**Practical**	**Total**
EEL504	**Power Electronics Lab (abbreviated as PE Lab)**	**-**	**2**	**-**	**1**	**1**

Course Code	Course Name	Examination Scheme							Total
		Theory				Practical			
		Internal Assessment			End Sem. Exam	Term Work	Pract. and Oral	Oral	
		Test 1	Test 2	Avg.					
EEL504	Power Electronics Lab	-	-	-	-	25	25	-	50

Course Objectives	• To impart knowledge about various power semiconductor devices related to its characteristics, ratings, protection and to select semiconductor devices for various applications. • To introduce different methods of power conversion such as ac to dc, dc to dc, dc to ac the underlying principles of converter operation and hence to analyse different converter circuits for power conversion. • To keep abreast with the latest technologies and research going on in different areas related to power electronics.
Course Outcomes	Student will be able to • Draw V-I characteristics of power electronic devices. • Simulate the performance of power electronic conversion systems. • Analyse various single phase and three phase power converter circuits and understand their applications. • Apply the basic concepts of power electronics to design the circuits in the fields of AC and DC drives, power generation and transmission and energy conversion, industrial applications. • Identify and describe various auxiliary circuits and requirements in power electronics applications such as Gate driver circuit, and snubber circuits along with electrical isolation and heat sinks

Syllabus: Same as that of Course EEC504 Power Electronics

Suggested List of Laboratory Experiment:

(A) Hardware Based Experiments

1. V-I Characteristics of SCR
2. Firing Circuit of SCR
3. Single phase half /full controlled rectifier circuit
4. Three phase half /fully controlled rectifier circuit with R load
5. Triac - Diac circuit based speed control of single phase motor
6. Gate Drive Circuit and snubber circuits (IGBT/MOSFET based)
7. Single phase Inverter (IGBT/MOSFET based)
8. Three phase Inverter (IGBT/MOSFET based)

9. Implementation of PWM techniques
10. Buck converter
11. Boost Converter /Buck-Boost
12. AC-AC converter

(B) Applications of Power Electronics Circuits Demonstration

13. Closed loop control of DC-DC converter
14. Power factor correction in converters
15. LED lamp intensity control
16. Solar PV based converter / inverter system

(C) Simulation

17. Three phase controlled rectifier including source inductance
18. PWM Rectifier
19. Three phase VSI (120° and 180° conduction mode)
20. Bidirectional DC-DC Converter
21. Buck Converter
22. AC voltage controllers: On-Off and phase control

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

Term work:

Term work shall consist of minimum six experiments and at least four simulations. 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.

Practical/Oral Examination:

Practical/Oral examination will be based on entire syllabus.

University of Mumbai						
Course Code	**Course Name**	**Teaching Scheme (Contact Hours)**		**Credits Assigned**		
		Theory	**Tutorial**	**Theory**	**Tutorial**	**Total**
EEC601	**Protection and Switchgear Engineering (abbreviated as PSE)**	**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	Protection and Switchgear Engineering	20	20	20	80	03	-	100

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

Module	Contents	Hours
1	**Substation Equipment and switching devices** **Substation Equipment:** Switchgear-Definition, Types, Location of switchgear in typical power system **Switching Devices**:- Isolator & Earthing switch (Requirements & definitions, types and construction, Pantograph Isolators, Ratings), Contactors: Basic working principle, Terms & Definitions, contactors as starters for motors, rated characteristics/ Utilization categories of contactors,	03
2	**Circuit Breakers and Fuses:** **Circuit Breaker:** Arc initiation, arc quenching principles, Restriking voltage, RRRV, Recovery voltage, Types of Circuit Breakers: MCB, MCCB, ELCB, air circuit breakers, oil circuit breakers, SF6 circuit breakers, vacuum circuit breakers (working principle, Construction, operating mechanisms, ratings & applications), Mechanical life, Electrical life and testing of circuit breakers. **HRC Fuses & their applications**-Introduction, types of devices with	09

	fuse, definitions, construction, fuse link of HRC fuse, Action of HRC fuse, shape of fuse element, specification of a fuse link, characteristics of fuse, cut-off, classification & categories, selection of fuse links, fuse for protection of motor, discrimination, fuse for protection of radial lines/meshed feeders, equipment incorporating fuses, high voltage current limiting fuses, expulsion type high voltage fuses, drop out fuse.	
3	**Introduction to Protective relaying:** About protective relaying, Shunt & Series Faults, causes and Effects of faults, Importance of protective relaying, Protective zones, primary & Back-up protection, Back-up protection by time grading principle, desirable qualities of protective relaying, some terms in protective relaying, Distinction between relay unit, protective scheme and Protective system, Actuating quantities, Thermal Relays, Electromechanical relays and static relays, Power line carrier channel, programmable relays, system security, role of engineers. **Electromagnetic relays** - Introduction, basic connections of relay, Auxiliary switch, sealing and auxiliary relays, measurement in relays, Pick up, drop off, Attracted armature & induction disc relays, Thermal, bimetal relays, Frequency relays, under/over voltage relays, DC relays, All or nothing relays. **Different Principles of protection** - Over current & earth fault (non-directional & directional types), differential protection, distance protection (Working Principle of Impedance relay, Causes and remedies of Over reach-under reach, Reactance and Mho relay, Power swing blocking relay).	09
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.	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 - Need for auto-reclosure schemes, Carrier aided distance protection (Directional comparison method), Power Line Carrier Current protection (Phase comparison method).	05
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), Distance relays as	04

	comparators. **Numerical Relays-** Introduction, Block diagram of numerical relay, Signal sampling, Anti –Aliasing Filter, Introduction to the concept of Phase Measurement Unit	

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

*7. Modern Power System Protection – DivyeshOza, TMH Publication

Assessment:

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

Theory Examination:

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

University of Mumbai						
Course Code	**Course Name**	**Teaching Scheme (Contact Hours)**		**Credits Assigned**		
		Theory	**Tutorial**	**Theory**	**Tutorial**	**Total**
EEC602	**Electrical Machines -IV (abbreviated as EMC - IV)**	**4**	**-**	**4**	**-**	**4**

Course code	Course Name	Examination Scheme						
		Theory					Term Work	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)		
		Test 1	Test 2	Avg.				
EEC602	Electrical Machines -IV	20	20	20	80	03	-	100

Course Objectives	• To impart knowledge of performance and operation of synchronous machine. • To study working, control and applications of brushless motor.
Course Outcomes	Students will be able • To determine the performance parameters of synchronous machines graphically and analytically by conducting different test. • To analyse the performance parameters of synchronous machines. • To understand the concept of direct and quadrature axis parameters of synchronous machines. • To understand and analyse the operation of synchronous motor. • To analyse abc to dq0 transformation and steady state operation of synchronous machine. • To understand the operation and analyse control of BLDC motors.

Module	Contents	Hours
1	**Synchronous Generator:** Construction, E.M.F. equation, Winding factors, Armature reaction, Phasor diagrams for cylindrical rotor generator, Voltage regulation, No load (OC) and SC test, Voltage regulation methods: EMF; MMF; ZPF; ASA; Saturated Synchronous Reactance.	12
2	**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, Numericals on parallel operation	08
3	**Salient pole synchronous generator:** Concept of direct and quadrature reactance, Blondel's two reaction theory, Phasor diagram of salient pole machine, Power angle characteristics, Synchronising power and torque.	05
4	**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	12

	X_q by slip test, Starting against high torques	
5	**Theory of Synchronous Machines:** Ideal synchronous machine, Transformation to direct and quadrature axis variables, basic machine relations in dq0 variables, Steady state analysis.	06
6	**BLDC Motor**: Classification**,** Construction, Electronic commutation, Principal of operation, Microprocessor/DSP based control scheme of BLDC motor (block diagram and flow chart), **S**ensor less control, Comparison with DC motor, Applications.	05

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
4. E.G.Janardanan, Special Electrical Machines, PHI Publisher, 2016.
5. K. Venkataratnam, Special Electrical Machines, University Press, 2016.

Reference Books:

1. Ashfaq Husain, Electric Machines, Dhanpat Rai and co. publications
2. A.E. Fitzgerald, Kingsly, Stephen., Electric Machinery, Tata McGraw Hill

Assessment:

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

Theory Examination:

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

University of Mumbai						
Course Code	**Course Name**	**Teaching Scheme (Contact Hours)**		**Credits Assigned**		
		Theory	**Tutorial**	**Theory**	**Tutorial**	**Total**
EEC603	**Signal Processing (abbreviated as SP)**	**3**	**1**	**3**	**1**	**4**

Course code	Course Name	Examination Scheme						
		Theory					Term Work	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)		
		Test 1	Test 2	Avg.				
EEC603	Signal Processing	20	20	20	80	03	25	125

Course Objectives	• To impart knowledge on continuous and discrete time signals.
Course Outcomes	Students will be able • To discriminate continuous and discrete time signals and systems. • To understand the transformation of discrete time signal to Z domain. • To analyse frequency response of systems using Z domain. • To understand discrete and fast Fourier transform. • To design FIR system. • To design IIR System.

Module	Contents	Hours
1	**Introduction** **Classification of Signal and System:** Definition and classification of continuous and discrete signals. Standard signals, periodic/non periodic, Even and odd, Energy and power signal, Sampling Theorem (Derivation is not Required), Basic operations on signal (Folding, Scaling and Time shifting). Definition and classification of systems: Causal /Anti causal, Time-Variant/Invariant, Linear/Non-Linear, stable/unstable, Memory/ Memory less System (static and dynamic). Convolution in DT domain (Matrix Method only)	06
2	**Z-Transform** Z-Transform of bilateral signal, Definition of ROC, Properties of ROC, Properties of Z-transform, Inverse Z-Transform (only partial fraction)	06
3	**Frequency Response** 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)	06
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	06

Books Recommended:

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. Li Tan," Digital Signal Processing, Fundamental & Application", Elsevier Publisher, Academic Press

Assessment:

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

Term work:

Term work shall consist of minimum eight tutorials and assignments (minimum 2). The distribution of marks for term work shall be as follows:

Tutorials :15 marks
Assignments :05 marks
Attendance (Theory and Tutorial) :05 marks

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

Theory Examination:

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

University of Mumbai						
Course Code	**Course Name**	**Teaching Scheme (Contact Hours)**		**Credits Assigned**		
		Theory	**Tutorial**	**Theory**	**Tutorial**	**Total**
EEC604	**Microcontroller and its Applications (abbreviated as MCA)**	**4**	**-**	**4**	**-**	**4**

Course code	Course Name	Examination Scheme						
		Theory					Term Work	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)		
		Test 1	Test 2	Avg.				
EEC604	Microcontroller and its Applications	20	20	20	03	80	-	100

Course Objectives	• To impart knowledge on PIC 18 microcontroller based embedded system using C programming.
Course Outcomes	Students will be able • To understand the features and architecture of PIC 18 microcontroller. • To understand the instructional set and apply to basic arithmetic and logical operations. • To understand the supportive devices of PIC 18 microcontrollers. • To understand the interfacing of PIC 18 microcontroller and it's peripheral. • To understand the coding of PIC 18 microcontroller using C language. • To design general purpose applications of PIC 18 microcontroller.

Module	Contents	Hours
1	**Introduction to Microcontroller** Block diagram of generic micro controller, Micro controller 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.	06
2	**PIC18F Programming Model and Instruction Set** PIC18 microcontroller programming model, Bus architecture, PIC microcontroller 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, Program Counter (PC) and program ROM, File Select Register (FSR) and File memory, Stack Pointer (STKPTR) and Stack, PIC 18 internal Architecture (ALU, EEPROM, RAM, IO Ports, Timer, CCP module, ADC), Concept of Pipelining. Instruction Set, Data transfer instructions, Arithmetic and Logical Instructions, Rotate instructions, Branch instructions, Bit manipulation instructions. (Assembly programs are restricted to basic	12

	arithmetic and logical operations only)`	
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 and 1), CCP module (Capture, Compare and PWM). ADC module: ADC Features, Block diagram of ADC module, ADC Registers, ADCON0, ADCON1. Interrupt Module: Basic concept of Interrupt, PIC 18 Interrupts, Interrupt versus polling, Interrupt sources, Interrupt vector, Interrupt service routine, Interrupt process, RCON Register, INTCON, IPR1, PIE1.	08
4	**Parallel Ports and Serial Communication** IO PORT Module: Basic concept of I/O interfacing, Port Registers, TRIS registers, LAT registers, Simple port interfacing and addressing, Interfacing input peripherals, Interfacing output peripherals. Serial communication: Basics of serial communication, 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 frequency. Interrupt programming: Timer0 and Timer1 interrupt to generate square wave. Serial port programming: Transmit data serially, Receive data serially.	08
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

Books Recommended:

Reference Books:

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

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.

Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Tutorial	Theory	Tutorial	Total
EEC605	**Control System -II (abbreviated as CS-II)**	**4**	**-**	**4**	**-**	**4**

Course code	Course Name	Examination Scheme						
		Theory					Term Work	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)		
		Test 1	Test 2	Avg.				
EEC605	Control System – II	20	20	20	80	03	-	100

Course Objectives	• To impart knowledge and skill on compensator design. • To study basics of digital control system and design of digital compensator.
Course Outcomes	Students will be able • To understand the basic design of various compensators. • To design compensators using root locus techniques. • To design compensators using frequency response techniques. • To design compensators using state variable approach. • To illustrate basics of digital control system. • To design digital compensators.

Module	Contents	Hours
1	**Introduction to the Compensator:** Basic concept of compensator design, its requirement, position of compensator in a control system, cascade compensator, feedback compensator, gain compensation, lag, lead and lag-lead compensator, proportional, derivative, integral Compensation, Three term PID, physical realization of compensator with passive and active components, basic block diagrams of a compensated closed loop control system	04
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, design of rate feedback compensator, notch filter,	12
3	**Design of Compensators using Frequency response Technique (Bode Plot):** Introduction, transient response improvement by gain adjustment, Lag compensation, Lead compensation, Lag-lead compensation.	10
4	**Design of Compensators using State variable approach:** Introduction, pole placement topology, controller design by pole placement topology in phase variable form, controllability and complete controllability, controllability matrix, controllability by inspection, alternative approach to controller design, controller design by transformation. Introduction to Observer / estimator, full order and reduced order observer/ estimator, observability matrix, observability by inspection, observer design by pole placement alternative approach to Observer	8

	design, Observer design by transformation, steady state error design using integral control.	
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	6
6	**Design of Digital Compensators:** 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.	8

Books Recommended:

Text books:

1. Control system engineering by Norman Nise 2nd to latest edition

2. Control Engineering: An Introductory course by Wilkie J., Johnson M., Katebi R., Palgrave MacMillan, Ist to latest edition

3. Industrial Control Electronics: Devices, Systems and Applications by Bartelt, Delmar Thomson Learning, 1st edition

4. Introduction to Programmable Logic Controller by Dunning G, Delmar Thomson Learning, 2nd 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

Assessment:

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

Theory Examination:

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

University of Mumbai

Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Tutorial	Theory	Tutorial	Total
EEDLO 6021	**Digital Communication Engineering (abbreviated as DCE)**	**3**	**1**	**3**	**1**	**4**

Course code	Course Name	Examination Scheme						
		Theory					Term Work	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)		
		Test 1	Test 2	Avg.				
EEDLO 6021	Digital Communication Engineering	20	20	20	80	03	25	125

Course Objectives	• To impart knowledge and skill on digital communication engineering.
Course Outcomes	Students will be able • To understand the concept and blocks of digital communication system. • To understand and analyse the performance of base band and pass band digital communication system. • To analyse the different modulation techniques used in digital communication system. • To identify the presence of error in coded signal and design the error control system. • To understand basic concept of different type of digital communication systems.

Module	Contents	Hours
1	**Information theory** Block diagram of a digital communication system, Concept and measures of information, entropy and it's properties. Transmission rate and channel capacity of noisy channels, Shannon's theorem on channel capacity. Source Coding, Shannon's Source Coding Theorem, Shannon-Fano Source Coding, Huffman Source Coding. Introduction to Lempel Ziv coding	06
2	**Baseband Modulation and Transmission** Line codes and their desirable properties, PSD of digital data. Discrete PAM signals and its power spectra. Concept of inter channel and inter symbol interference, Nyquist criterion for zero ISI, sinusoidal roll-off filtering, correlative coding, equalizers, and eye pattern. Duo-binary encoding and modified duo-binary encoding	06
3	**Baseband Detection** Orthogonality, representation of signals. Maximum likelihood decoding Correlation receiver, equivalence with matched filter	04
4	**Modulation Techniques** Generation, detection, Coherent and non-coherent reception, signal space diagram, spectrum, bandwidth efficiency, and probability of error	08

	analysis of : Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK)Modulations, Binary Phase Shift Keying (BPSK) Modulation Quaternary Phase Shift Keying QPSK)	
5	**5. Error Control Systems**:- **5.1** Types of error control, error control codes, linear block codes, generator matrix, and systematic linear block. codes, parity check matrix, syndrome testing ,error correction, and decoder implementation **5.2** Cyclic codes: Algebraic structure of cyclic codes, binary cyclic code properties, encoding in systematic **5.3** Introduction of Convolution code: State diagram, code tree, trellis diagram	08
6	**Overview of different types of communication** :- Power Line Carrier communication, Satellite communication, OFC (Block Diagram level)	04

Books Recommended:

Text Books:

1. Tomasi W. , "Advanced Electronics Communication systems",PGI,4th Edition1998
2. Taub & Schiling, "Principles of Communication Systems", McGraw Hill, 2nd Ed. 1987
3. John C. proakis, "Digital Communication", McGraw Hill International, 1995
4. Haykin S, John Wiley & Sons, "Digital Communication", 3rd Ed. 1995

Reference Books:

1. Lathi B.P., "Modern Digital and Analog Communication System, Oxford University Press, 3rd Edition 1998
2. Dennis Roddy and John Coolen, "Electronic Communications", Prentice Hall of India, 3rd Ed. 1992
3. Amitabha Bhattacharya, "*Digital Communication*", Tata Mcgraw Hill

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

Term work:

Term work shall consist of minimum eight tutorials and assignments (minimum 2). The distribution of marks for term work shall be as follows:

Tutorials :15 marks
Assignments :05 marks
Attendance (Theory and Tutorial) :05 marks

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

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.

Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Tutorial	Theory	Tutorial	Total
EEDLO 6022	**Micro-Grid (abbreviated as MG)**	**3**	**1**	**3**	**1**	**4**

Course code	Course Name	Examination Scheme						
		Theory					Term Work	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)		
		Test 1	Test 2	Avg.				
EEDLO 6022	Micro-Grid	20	20	20	80	03	25	125

Course Objectives	• To impart knowledge of renewable energy based Microgrid technology, types and issues associated in their practical realization. • To elaborate the various control and operational strategies used for practical microgrids.
Course Outcomes	Students will be able • To identify and describe the evolvement Microgrid, its features and barriers. • To select, size and design the various microgrid resources. • To model, analyze and design the power electronics (PE) interfaces for various microgrid sources • To identify and describe the role communication in Microgrid realization. • To identify and describe various operational strategies and protection schemes suitable for Microgrid. • To apprise the different standards applicable for microgrid deployment

Module	Contents	Hours
1	**Introduction to Microgrid:** Microgrid: Definition, What is not a microgrid, Typical structure and configuration of a microgrid, Significance of microgrids, Sources of microgrid, Types of microgrids, AC, DC and hybrid microgrids; Technical implications and social fall out of microgrid, Market Models and business cases for microgrids.	03
2	**Microgrid Sources and Power Electronic Interfaces:** Review of Microgrid sources: basics characteristics and selection; Power Electronics (PE) interface and design for microgrid DC and AC sources. Protection and co-ordination, Power Quality issues and Solutions; Microgrid and Energy Storage Systems (ESS), Portable and Stationary ESS, Review of Flywheel, Battery and Ultra-capacitor; PE Interface design for ESS.	08
3	**Control and Design of Power Electronic Interfaces:** Determination of Control laws, Power relations and power control, Bi-directionality and its need in a Microgrid; Control of DC-DC converters and inverter and challenges in a Microgrid; Micro-grid Control Strategies: Centralized, Decentralized and Hierarchical control, Multi-Agent System based control; Power Control and Energy Management in Microgrids.	10

4	**Communication Infrastructure:** Requirement of Communication System in microgrids, Communication protocols and standards; Selection of communication protocols for microgrids. Event triggered system and Time triggered system, Unicast and Multicast Communication, Impact of time latencies on operation.	05
5	**Operation of Microgrid and Microgrid Protection:** Modes of Operation: Grid Connected Mode, Islanding Mode, Issues in Island Mode of operations, Islanding detection, Reliability and Stability Issues in islanding ; Protection: Fault Behavior in Grid Connected Mode and Island mode, Types of Protection Systems Fault Source Based protection, Adaptive protection.	07
6	**Microgrid Standards and Deployment:** IEEE-1547 series, Review of worldwide Microgrid installations, Economic evaluation and planning for microgrids; Microgrids in smart grid scenario.	03

Books Recommended:

Text Books:

1. Nikos Hatziargyriou, "Microgrids: Architectures and Control," Wiley-IEEE Press, 2013
2. Magdi S Mahmoud, "Microgrid: Advanced Control Methods and Renewable Energy System Integration", Butterworth-Heinemann, 2016
3. S. M. Sharkh , M. A. Abu-Sara, G. I. Orfanoudakis and B. Hussain, "Power Electronic Converters for Microgrids," Wiley – IEEE Press
4. Remus Teodorescu, Marco Liserre and Pedro Rodriguez, "Grid Converters for Photovoltaic and Wind Power Systems," Wiley Publications
5. Amirnaser Yazdani and Reza Iravani, "Voltage-Sourced Converters in Power Systems: Modeling, Control, and Applications," Wiley-IEEE Press

Reference Books:

1. Smart Grid:Fundamentals of Design and Analysis by James Momoh, IEEE Press and
2. Wiley Publications
3. Ali Keyhani, Mohammad N. Marwali, Min Dai "Integration of Green and Renewable Energy in Electric Power Systems", Wiley
4. Clark W. Gellings, "The Smart Grid: Enabling Energy Efficiency and Demand Response" CRC Press

Assessment:

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

Term work:

Term work shall consist of minimum eight tutorials and assignments (minimum 2). The distribution of marks for term work shall be as follows:

Tutorials :15 marks
Assignments :05 marks
Attendance (Theory and Tutorial) :05 marks

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

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.

Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Tutorial	Theory	Tutorial	Total
EEDLO 6023	**Advanced Power Electronics (abbreviated as APE)**	**3**	**1**	**3**	**1**	**4**

Course code	Course Name	Examination Scheme						
		Theory					Term Work	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)		
		Test 1	Test 2	Avg.				
EEDLO 6023	Advanced Power Electronics	20	20	20	80	03	25	125

Course Objectives	• To understand dc to dc conversion with isolation, the underlying principles of converter operation and hence to analyze different converter circuits for power conversion. • To understand the principles of design of magnetics such as high frequency transformers and inductors. • To keep abreast with the latest technologies and research going on in different areas related to power electronics. • To enhance the capability of problem solving skills. • To model the converter and design the controller for deeper understanding and detailed analysis.
Course Outcomes	Student will be able to • Select and design power electronic converter topologies for a broad range of energy conversion applications. • Analyze and simulate the performance of power electronic conversion systems. • Ability to model and design controllers for the closed loop operation of power converters. • Apply the basic concepts of power electronics to design the circuits in the fields of AC and DC drives, power generation and energy conversion, industrial applications, extraction of energy from renewable sources. • Build and troubleshoot power electronics circuits. • Deliver technological solution in the field of power electronics.

Module	Contents	Hours
1	Switching Voltage Regulators Introduction; Linear power supply (voltage regulators); Switching voltage regulators; unidirectional and bidirectional core excitation; Review of basic dc-dc voltage regulator configurations -Buck, Boost, Buck-Boost converters, Bidirectional Converter (BDC) and their analysis for continuous and discontinuous mode; Other converter configurations like Flyback converter, Forward converter, Push-pull converter; Design criteria for SMPS; Multi-output switch mode regulator.	10

2	**Resonant dc to dc converters:** Drawbacks of switch-mode converters, classification of resonant converters, basic resonant circuit concepts, Load resonant converters, series and parallel loaded, steady state operating characteristics, Resonant switch converters - ZVS, ZCS, comparison of resonant converters, applications of resonant converters	03
3	**Design of Magnetics (Boost, Buck, BDC and flyback only).:** Review of magnetic concepts, volt-sec balance, area product, design of inductor, design of high frequency transformer, numericals on design of inductor and transformer for dc to dc converters.	05
4	**Modeling and control converters and inverter (Boost, Buck, BDC and flyback only):** State space model of various dc to dc converters, state space averaging techniques, small signal analysis, transfer function, feedback control, compensator design, voltage mode control, current mode control. Modeling of grid connected Inverter with LC filter, Compensator design with current mode control and DC link voltage control loop. Digital control of power electronic converters	09
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, Applications of multilevel inverters.	04
6	**Applications of power electronic converters:** Solar PV Power Conditioning unit (PCU), Battery PCU, Active Filters, AC and DC drives. Thermal management and EMI issues in Practical power Electronics systems	05

Books Recommended:

Text Books:

1. N.Mohan, T.M.Undeland, W.P Robbins, ―Power Electronics, Converters, Applications & Design, Wiley India.
2. R W Erickson and D Maksimovic, ―Fundamental of Power Electronics, Springer, 2nd Edition.
3. M.H.Rashid, Hand book of Power Electronics" , Third edition Butterworth-Heinemann; 2011
4. Joseph Vithayathil ―Power Electronics‖, Tata McGraw Hill
5. Daniel.W.Hart, "Power Electronics", Mc GrawHill Publications 2010
6. P.S Bhimbra, "Power Electronics",Khanna Publishers.
7. Simon Ang, Alejandro Oliva, "Power-Switching Converters" Taylor and Francis group
8. L.Umanand, "Design of Magnetic Components for Switched Mode Power Converters", New Age International

Reference Books:

1. P. T. Krein, Elements of Power Electronics, Oxford University Press.
2. L. Umanad, "Power Electronics: Essentials & Applications," Wiley.
3. A Yazdani, R. Iravani, Voltage- Sourced Converters in Power Systems, Wiley, IEEE press.

Assessment:

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

Term work:

Term work shall consist of minimum six tutorials and one group mini project.

Mini-project: Group of students (4 in a group) will choose a fairly complex power electronics application in their preferred area, complete the analysis and detailed design of power converter and control for this application, and finally validate the design using hardware implementation supported with simulation(if necessary). A formal technical report is required on the last day of class.

The distribution of marks for term work shall be as follows:

Tutorials	:10 marks
Group Mini Project	:10 marks
Attendance (Theory and Tutorial)	:05 marks

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

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.

Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Practical	Theory	Practical	Total
EEL601	**Electrical Protection Lab (abbreviated as EP Lab)**	**-**	**2**	**-**	**1**	**1**

Course Code	Course Name	Examination Scheme							Total
		Theory				Practical			
		Internal Assessment			End Sem. Exam	Term Work	Pract. and Oral	Oral	
		Test 1	Test 2	Avg.					
EEL601	Electrical Protection Lab	-	-	-	-	25	-	25	50

Course Objectives	• To introduce the concept of different protection schemes.
Course Outcomes	Students will be able • To understand the concept of various over current protection scheme and its applications in power system. • To understand the concept of various over/under voltage, over/under frequency and temperature protection scheme and its applications. • To understand the working principle of various protective devices.

Syllabus: Same as that of Course EEC601 protection and switchgear Engineering.

Suggested List of Laboratory Experiment:

1. Demonstration of Inverse time Over-current Relay & Plotting the characteristics
2. Demonstration of Over-current protection Relay
3. Demonstration of Directional Over-current Protection Relay
4. Demonstration of Differential Over-current Protection Relay
5. Demonstration of Under/Overvoltage Protection
6. Demonstration of Motor winding temperature protection
7. Demonstration of Gas actuated Relays
8. Demonstration of working parts of different Fuses, MCB, MCCB, RCCB & Circuit Breakers.
9. Visit to a substation & a report preparation.

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

Term work:

Term work shall consist of minimum six 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.

University of Mumbai			
Course	**Course Name**	**Teaching Scheme**	**Credits Assigned**

Code		(Contact Hours)				
		Theory	**Practical**	**Theory**	**Practical**	**Total**
EEL602	**Electrical Machines Lab - IV (abbreviated as EMC Lab-IV)**	**-**	**2**	**-**	**1**	**1**

Course Code	Course Name	Examination Scheme							Total
		Theory				Practical			
		Internal Assessment			End Sem. Exam	Term Work	Pract. and Oral	Oral	
		Test 1	Test 2	Avg.					
EEL602	Electrical Machines Lab -IV	-	-	-	-	25	25	-	50

Course Objectives	• To impart practical knowledge on synchronous machines
Course Outcomes	Students will be able • To analyse the operation of synchronous machines. • To analyse the voltage regulation of synchronous machines. • To analyse the synchronization or parallel operation of synchronous machine. • To determine the parameters of synchronous machines for its analysis.

Syllabus: Same as that of Course EEC602 Electrical machines - IV

Suggested List of Laboratory Experiment:

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. 'V' and inverted 'V' curve of Synchronous motor
8. Determination of X_d and X_q of Synchronous machine by Slip test
9. Use of Synchronous motor as a Synchronous condenser
10. Loading of Synchronous motor by Brake test with rated excitation

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

Term work:

Term work shall consist of minimum six 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.

Practical/Oral Examination:
Practical/Oral examination will be based on entire syllabus.

Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Practical	Theory	Practical	Total
EEL603	**Microcontroller Lab (abbreviated as MC Lab)**	**-**	**2**	**-**	**1**	**1**

Course Code	Course Name	Examination Scheme							Total
		Theory				Practical			
		Internal Assessment			End Sem. Exam	Term Work	Pract. and Oral	Oral	
		Test 1	Test 2	Avg.					
EEL603	Microcontroller Lab	-	-	-	-	25	25	-	50

Course Objectives	• To impart the programming knowledge of PIC 18 microcontroller.
Course Outcomes	Students will be able • To program simple arithmetic and logical operations using PIC 18 microcontroller. • To program timer and ADC of PIC 18 microcontroller for different applications. • To interface different IO devices with PIC 18 microcontroller.

Syllabus: Same as that of Course EEC604 Microcontroller and its applications

Suggested List of Laboratory Experiment:

Basic Programming

1. Addition, subtraction
2. Logical operations
3. Multiplication and division
4. Sort even and odd numbers
5. Sort negative and positive numbers
6. Toggle the bits of ports

Timer programming

1. Generate square wave
2. Generate time delay
3. Counter program
4. Generate the PWM pattern

ADC programming

1. Analog to digital conversion

Peripheral Interface programming

1. LCD interface
2. LED interface
3. Stepper motor interface
4. DC motor interface
5. Serial port interface

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

Term work:

The term work shall consist of minimum **eight** experiments based on PIC 18F microcontroller using embedded C language. 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.

Practical/Oral Examination:

Practical/Oral examination will be based on entire syllabus.

University of Mumbai						
Course Code	**Course Name**	**Teaching Scheme (Contact Hours)**		**Credits Assigned**		
		Theory	**Practical**	**Theory**	**Practical**	**Total**
EEL604	**Simulation Lab-II (abbreviated as Sim Lab - II)**	**-**	**2**	**-**	**1**	**1**

Course Code	Course Name	Examination Scheme							Total
		Theory				Practical			
		Internal Assessment			End Sem. Exam	Term Work	Pract. and Oral	Oral	
		Test 1	Test 2	Avg.					
EEL604	Simulation Lab-II	-	-	-	-	25	-	25	50

Course Objectives	• To impart knowledge on coding and simulation of electrical systems.
Course Outcomes	Students will be able • To code or simulate signal systems for its analysis. • To code or simulate power system for its analysis. • To code or simulate power electronics converter for its analysis. • To code or simulate electrical machines for its analysis.

Syllabus: Same as that of all core courses of semester VI.

Suggested List of Laboratory Experiment:

1. Algorithm for Basic operation on signal
2. Algorithm for Linear and Circular Convolution
3. Algorithm for step, impulse and frequency Response in Digital system
4. Algorithm for FFT for DFT Computation
5. Algorithm for Design of FIR System using Rectangular Window
6. Algorithm for Design of Butterworth Digital IIR System
7. Simulation of 1- phase full wave Rectifier with R-L Load
8. Simulation of Fault Analysis
9. Simulation of OC & SC Test of 3-phase IM.
10. Simulation of 1- phase full wave Controlled Rectifier with R-L Load

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

Term work:

Term work shall consist of minimum six 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.