Four-year Bachelor of Technology (BTech)
Degree Program
in
Electrical and Electronics Engineering (EEE)

by

Department of Electrical Engineering Department

Indian Institute of Technology Patna

Bihta, Patna-801106

Academic Program: Bachelor of Technology (B.Tech.) in Electrical and Electronics Engineering (EEE)

Program Learning Objectives: 1. Develop a solid foundation in electrical and electronics engineering principles, including circuit analysis, electromagnetic field theory, electrical machines, power systems, control systems, power electronics, signal processing, and microprocessor/microcontroller systems. 2. Develop electrical and electronics project management skills, including the ability to plan, execute, and complete within specified timelines and budgets. 3. Work collaboratively in multidisciplinary teams, demonstrating effective teamwork and communication to solve complex engineering problems. 4. Recognize the importance of ongoing professional development, engaging in activities such as certifications, workshops, and conferences to stay updated of industry trends.	**Program Learning Outcomes:** The graduates of this program will have 1. a successful career in an Academia/Industry/Entrepreneur 2. strong fundamentals in electrical and electronics engineering. 3. ability to design prototypes for real world problems related to electrical, electronics, and interdisciplinary fields. 4. ability to develop soft skills such as effective communications in both verbal and written forms, body language, time managements, problem-solving, leadership, work in both team as well as individual in a professional manner
Program Goal 1: Academic excellence by providing a curriculum that aligns with industry standards and encourages critical thinking in electrical and electronics engineering**.**	**Program Learning Outcome 1a:** Highly skilled market ready manpower to serve the emerging electrical and electronic sectors **Program Learning Outcome 1b:** Skilled Human resource to cater the needs of next generation power systems and EV technologies.
Program Goal 2: A culture of research and innovation by promoting faculty and student involvement in innovative projects in electrical and electronic technologies.	**Program Learning Outcome 2a:** Trained researchers for implementing research projects in line with national priorities such as Energy, EVs, Smart Grids, Green Technologies **Program Learning Outcome 2b:** Design and develop innovative smart technologies/products in energy and EVs as per the societal need
Program Goal 3: To design dynamic and flexible course structures for UG and PG programs as per the changing requirement of the industries	**Program Learning Outcome 3a:** Industry relevant UG, PG, and research programs **Program Learning Outcome 3b:** Trained manpower as per the industry requirement
Program Goal 4: To promote entrepreneurship among the students in the field of electrical and electronics engineering	**Program Learning Outcome 4a:** Realization of working prototype towards product development **Program Learning Outcome 4b:** Promotion of in-house technology-based ventures catering societal needs
Program Goal 5: Equip students with effective communication skills, enabling them to articulate technical concepts clearly and effectively in both written and oral forms.	**Program Learning Outcome 5a:** Manpower with enhanced soft skills to support the vision of developed India **Program Learning Outcome 5b:** Responsible citizen for the holistic growth of the country

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Sl. No.	Subject Code	**SEMESTER I**	**L**	**T**	**P**	**C**
1.	MA1101	Mathematics I (Calculus and Linear Algebra)	3	1	0	4
2.	CS1101	Foundations of Programming	3	0	3	4.5
3.	PH1101/ PH1201	Physics	3	1	3	5.5
4.	CE1101/ CE1201	Engineering Graphics	1	0	3	2.5
5.	EE1101/ EE1201	Electrical Sciences	3	0	3	4.5
6.	HS1101	English for Professionals	2	0	1	2.5
TOTAL			**15**	**2**	**13**	**23.5**

Sl. No.	Subject Code	**SEMESTER II**	**L**	**T**	**P**	**C**
1.	MA1201	Mathematics II (Probability and ODE)	3	1	0	4
2.	CS1201	Data Structure	3	0	3	4.5
3.	CH1201/ CH1101	Chemistry	3	1	3	5.5
4.	ME1201/ ME1101	Workshop Practice	0	0	3	1.5
5.	ME1202/ ME1102	Engineering Mechanics	3	1	0	4
6.	IK1101	Indian Knowledge System (IKS)	3	0	0	3
TOTAL			**15**	**3**	**9**	**22.5**

Sl. No.	Subject Code	**SEMESTER III**	**L**	**T**	**P**	**C**
1.	EE2101	Measurements and Instrumentation	3	0	2	4
2.	EE2102	Network Analysis and Synthesis	3	0	0	3
3.	EC2101	Analog Circuits	3	0	2	4
4.	EC2102	Signals and Systems	3	1	0	4
5.	EE2103	Electrical Machines – I	2	0	2	3
6.	HS21PQ	HSS Elective I	3	0	0	3
TOTAL			**17**	**1**	**6**	**21**

Sl. No.	Subject Code	**SEMESTER IV**	**L**	**T**	**P**	**C**
1.	EC2201	Digital Electronics	3	0	2	4
2.	EC2202	Microprocessor	2	0	2	3
3.	EE2201	Control Systems	3	0	2	4
4.	EE2202	Electrical Machines-II	2	0	2	3
5.	EC2204	Internet of Things	3	0	0	3
6.	XX22PQ	IDE I	3	0	0	3
TOTAL			**16**	**0**	**8**	**20**

Sl. No.	Subject Code	**SEMESTER V**	**L**	**T**	**P**	**C**
1.	EC3101	Microcontroller and Embedded System	3	0	2	4
2.	EE3101	Power Systems-I	2	0	2	3
3.	EE3102	Modern Control Theory	3	0	2	4
4.	EC3104	Engineering Electromagnetics	3	0	0	3
5.	EC3105	Random Signals and Stochastic Processes	3	0	0	3
6.	XX31PQ	IDE II	3	0	0	3
TOTAL			**17**	**0**	**6**	**20**

Sl. No.	Subject Code	**SEMESTER VI**	**L**	**T**	**P**	**C**
1.	EE3201	Fundamentals of Electric Drives	3	0	2	4
2.	EC3202	Digital Signal Processing	3	0	2	4
3.	EC3203	Introduction to AI/ML	3	0	0	3
4.	EE3202	Power System II	3	0	2	4
5.	EE3203	Power Electronics	3	0	2	4
6.	EE3204	Electrical Machine Design	1	0	2	2
TOTAL			**16**	**0**	**10**	**21**

Sl. No.	Subject Code	**SEMESTER VII**	L	T	P	C
1.	EE41xx	Departmental Elective – I	3	0	0	3
2.	EE41xx	Departmental Elective – II	3	0	0	3
3.	HS41PQ	HSS Elective II	3	0	0	3
4.	XX41PQ	IDE III	3	0	0	3
5.	EE4198	Summer Internship*	0	0	12	3
6.	EE4199	Project – I	0	0	12	6
TOTAL			**12**	**0**	**24**	**21**

Sl. No.	Subject Code	**SEMESTER VIII**	**L**	**T**	**P**	**C**
1.	EE42xx	Departmental Elective – III	3	0	0	3
2.	EE42xx	Departmental Elective – IV	3	0	0	3
3.	EE42xx	Departmental Elective – V	3	0	0	3
4.	EE4299	Project – II	0	0	16	8
TOTAL			**9**	**0**	**16**	**17**
GRAND TOTAL						**166**

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List of Department Electives

Department Elective I	**Department Elective II**
EE4101 Electrical Traction and Propulsion	EC4101 Introduction to Quantum Computing
EC4102 Deep Learning for Video Surveillance Systems	EC4105 Digital Image Processing
EC4103 FPGA based System Design	EE4102 Power System Reliability

Department Elective III	**Department Elective IV**	**Department Elective V**
EE4201 Power System Protection	EE4204 Special Electrical Machines	EC4205 Biomedical Signal Processing
EE4202 Digital Control Systems	EE4205 High Voltage Engineering	EC4206 High Power Semiconductor Devices
EE4203 Introduction to Energy Storage Techniques	EE4206 Fundamentals of Electrical Vehicle Technology	EC4207 Biomedical Instrumentation

Course Number	**EE1101/EE1201**
Course Credit	**3-0-3-4.5**
Course Title	**Electrical Sciences**
Learning Mode	Lectures and Experiments
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	The course is designed to meet the requirements of all B. Tech programmes. The course aims at giving an overview of the entire electrical engineering domain from the concepts of circuits, devices, digital systems and magnetic circuits.
Course Outline	Circuit Analysis Techniques, Circuit elements, Simple RL and RC Circuits, Kirchoff's law, Nodal Analysis, Mesh Analysis, Linearity and Superposition, Source Transformations, Thevenin's and Norton's Theorems, Time Domain Response of RC, RL and RLC circuits, Sinusoidal Forcing Function, Phasor Relationship for R, L and C, Impedance and Admittance, Instantaneous power, Real, reactive power and power factor. Semiconductor Diode, Zener Diode, Rectifier Circuits, Clipper, Clamper, UJT, Bipolar Junction Transistors, MOSFET, Transistor Biasing, Transistor Small Signal Analysis, Transistor Amplifier and their types, Operational Amplifiers, Op-amp Equivalent Circuit, Practical Op-amp Circuits, Power Opamp, DC Offset, Constant Gain Multiplier, Voltage Summing, Voltage Buffer, Controlled Sources, Instrumentation Amplifier, Active Filters and Oscillators. Number Systems, Logic Gates, Boolean Theorem, Algebraic Simplification, K-map, Combinatorial Circuits, Encoder, Decoder, Combinatorial Circuit Design, Introduction to Sequential Circuits. Magnetic Circuits, Mutually Coupled Circuits, Transformers, Equivalent Circuit and Performance, Analysis of Three-Phase Circuits, Power measurement in three phase system, Electromechanical Energy Conversion, Introduction to Rotating Machines (DC and AC Machines). <u>Laboratory:</u> Experiments to verify Circuit Theorems; Experiments using diodes and bipolar junction transistor (BJT): design and analysis of half -wave and full-wave rectifiers, clipping and clamping circuits and Zener diode characteristics and its regulators, BJT characteristics (CE, CB and CC) and BJT amplifiers; Experiment on MOSFET characteristics (CS, CG, and CD), parameter extraction and amplifier; Experiments using operational amplifiers (op-amps): summing amplifier, comparator, precision rectifier, Astable and Monostable Multivibrators and oscillators; Experiments using logic gates: combinational circuits such as staircase switch, majority detector, equality detector, multiplexer and demultiplexer; Experiments using flip-flops: sequential circuits such as non-overlapping pulse generator, ripple counter, synchronous counter, pulse counter and numerical display; Power Measurement by two Wattmeter method; Open and Short Circuit Tests of Transformer.
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Text/References** 1. C. K. Alexander, M. N. O. Sadiku, Fundamentals of Electric Circuits, 3rd Edition, McGraw-Hill, 2008. 2. W. H. Hayt and J. E. Kemmerly, Engineering Circuit Analysis, McGraw-Hill, 1993. 3. R. L. Boylestad and L. Nashelsky, Electronic Devices and Circuit Theory, 6th Edition, PHI, 2001. 4. M. M. Mano, M. D. Ciletti, Digital Design, 4th Edition, Pearson Education, 2008. 5. Floyd, Jain, Digital Fundamentals, 8th Edition, Pearson. 6. David V. Kerns, Jr. J. David Irwin, Essentials of Electrical and Computer Engineering, Pearson, 2004. 7. Donald A Neamen, Electronic Circuits; analysis and Design, 3rd Edition, Tata McGraw-Hill Publishing Company Limited. 8. Adel S. Sedra, Kenneth C. Smith, Microelectronic Circuits, 5th Edition, Oxford University Press, 2004. 9. A. E. Fitzgerald, C. Kingsley Jr., S. D. Umans, Electric Machinery, 6th Edition, Tata McGraw-Hill, 2003. 10. D. P. Kothari, I. J. Nagrath, Electric Machines, 3rd Edition, McGraw-Hill, 2004. 11. Del Toro, Vincent. "Principles of electrical engineering." (No Title) (1972).

Course Number	**EE2101**
Course Credit	**3-0-0-3**
Course Title	**Measurements and Instrumentation**
Learning Mode	Lectures and Experiments
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	The course deals with the basic of instrumentation and measurements of several commonly known physical variables. It also introduces signal conditioning and modern electronics equipment.
Course Outline	Definition of instrumentation. Static characteristics of measuring devices. Error analysis, standards and calibration. Dynamic characteristics of instrumentation systems. Electromechanical indicating instruments: ac/dc current and voltage meters, ohmmeter; loading effect. Measurement of power and energy; Instrument transformers. Measurement of resistance, inductance, capacitance. ac/dc bridges. Measurement of non-electrical quantities: transducers classification; measurement of displacement, strain, pressure, flow, temperature, force, level and humidity. Signal conditioning; Instrumentation amplifier, Isolation amplifier, and other special purpose amplifiers. EMI and EMC, shielding, earthing and grounding. signal recovery, data transmission and telemetry. data acquisition and conversion. Modern electronic equipment: oscilloscope, DMM, frequency counter, wave/ network/ harmonic distortion/ spectrum analyzers, logic probe and logic analyzer. Data acquisition system; PC based instrumentation. Programmable logic controller: ladder diagram. Computer controlled test systems, serial and parallel interfaces, Field buses. Smart sensors (Voltage, Current and Temperature sensors). Laboratory: Experiments on displacement, temperature, strain, flow, acceleration measurements, AC bridges, PLC, instrumentation amplifier, encoder, Measurement of capacitance, inductance and resistance.
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Text/References** 1. A. D. Helfrick and W. D. Cooper, Modern Electronic Instrumentation and Measuring Techniques, Pearson Education, 1996. 2. M. M. S. Anand, Electronic Instruments and Instrumentation Technology, PHI, 2006. 3. E. O. Deobelin, Measurement Systems - Application and Design, Tata McGraw-Hill, 1990. 4. B. E. Jones, Instrumentation, measurement, and Feedback, Tata McGraw-Hill, 2000. 5. R. P. Areny and T. G. Webster, Sensors and Signal Conditioning, John Wiley, 1991. 6. B. M. Oliver and J. M. Cage, Electronic Measurements and Instrumentation, McGraw-Hill, 1975. 7. C. F. Coombs, Electronic Instruments Handbook, McGraw-Hill, 1995. 8. R. A. Witte, Electronic Test Instruments, Pearson Education, 1995. 9. B. G. Liptak, Instrument Engineers' Handbook: Process Measurement and Analysis, Chilton Book, 1995.

Course Number	**EE2102**
Course Credit	**3-0-0-3**
Course Title	**Network Analysis and Synthesis**
Learning Mode	Lectures
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	The course is designed to meet the requirements of B. Tech. The course aims at giving detail of network theorems, graph theory and analysing and designing electrical circuits.
Course Outline	Overview of network analysis techniques, network theorems, transient and steady state sinusoidal response. Graph theory: basic definitions of loop (or tie set), cut-set, mesh matrices and their relationships, applications of graph theory in solving network equations. Two-port and *N*-Port networks, *Z*, *Y*, *h*, *g* and transmission parameters, combination of two ports, Analysis of common two port networks, pie and t-networks.

	Network functions, parts of network functions, obtaining a network function from a given part. Network transmission criteria; delay and rise time. Elements of network synthesis techniques, Cauer and Foster forms, Butterworth and Chebyshev Approximation.
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments, and Exams
Suggested Reading	**Text/ References:** 1. F. F. Kuo, Network Analysis and Synthesis, John. Wiley, 2006. 2. M. E. V. Valkenburg, Network Analysis 3rd Edition 3. R. J. Trudeau, Introduction to graph theory. Courier Corporation, 2013.

Course Number	**EC2101**
Course Credit	**3-0-2-4**
Course Title	**Analog Circuits**
Learning Mode	Lectures and Experiments
Learning Objectives	Complies with Program Goal 1 and 2
Course Description	The course deals with various analog sub circuits including analog circuits such as amplifiers, differential amplifiers, filters and oscillators. It also focuses on design and implementation of various analog circuits like amplifiers - single transistor amplifiers, cascade amplifiers, differential amplifiers, filters and oscillators.
Course Outline	**CMOS realizations:** current source, sink and mirrors, differential amplifiers, multistage amplifiers; **Differential amplifiers:** DC and small signal analysis, CMRR, current mirrors, active load and cascade configurations; **Frequency response of amplifiers:** high frequency device models, frequency responses of various amplifiers, GBW, methods of short circuit and open circuit time constants, dominant pole approximation; **Analog subsystems:** analog switches, voltage comparator, voltage regulator, switching regulator, bandgap reference voltage source, analog multiplier, **Filter approximations**: Butterworth, Chebyshev, first order and second order passive/active filter realizations of LPF, HPF, BPF. **Signal generation and waveform shaping:** Schmitt trigger, relaxation oscillators, sinusoidal oscillators – RC, LC, and crystal oscillator; **Feedback amplifiers:** basic feedback topologies and their properties, analysis of practical feedback amplifiers, stability; **Power amplifiers:** efficiency of class A, B, AB, C, D stages, output stages, short circuit protection, power transistors and thermal design considerations; **Case study:** 741 op-amp - DC and small signal analysis, frequency response, frequency compensation, GBW, phase margin, slew rate, offsets; Laboratory: Experiments on advanced applications of BJTs- and FETs-based circuits, Op-amps and other integrated circuits, Multistage amplifiers, Automatic gain controlled amplifiers, programmable gain amplifiers, Frequency response of amplifiers; waveform generators, Active filters, Feedback circuits and analysis, Current mirroring, 555 timer-based circuit design.
Learning Outcomes	Complies with PLO 1a, 2a, 2b
Assessment Method	Quiz, Assignments, and Exams

Suggested Reading	**Textbooks:** 1. A. S. Sedra and K. C. Smith, Microelectronics Circuits, 5th Edition, 2005, Oxford University Press. 2. P. Gray, P. Hurst, S. Lewis and R. Meyer, Analysis & Design of Analog Integrated Circuits, 4th Edition, 2001, Wiley. 3. B. Razavi, Fundamental of Microelectronics, 1st Edition, 2009, Wiley. 4. A. Malvino and D. Bates, Electronic Principles, 7th Edition, 2017, McGraw-Hill. 5. R. A. Gayakwad, Op-Amps and Linear Integrated Circuit, 4th Edition, 2002, Prentice Hall. **Reference Books:** 1. B. Carter and R. Mancini, Op Amaps for Everyone, 3rd Edition, 2009, Texas Instruments. 2. D. Johns, T. C. Carusone and K. Martin, Analog Integrated Circuit Design, 2nd Edition, 2011, Wiley. 3. R. A. Gayakwad, Op-Amps and Linear Integrated Circuit, 4th Edition, 2002, Prentice Hall. 4. P. E. Allen and D. R. Holberg, CMOS Analog Circuit Design, 2nd Edition, 1997, Oxford University Press.

Course Number	**EC2102**
Course Credit	3-1-0-4
Course Title	**Signals and Systems**
Learning Mode	Lectures and Tutorials
Learning Objectives	Complies with Program Goal 1 and 2
Course Description	The course deals with fundamental concepts of signals and systems including its application, analysis of impulse response of systems and frequency response using transforms such as CTFT, Laplace, DTFT, ZT, DFT.
Course Outline	Signals: classification of signals; signal operations: scaling, shifting and inversion; signal properties: symmetry, periodicity and absolute integrability; elementary signals. Systems: classification of systems; system properties: linearity, time/shift-invariance, causality, stability; continuous-time linear time invariant (LTI) and discrete-time linear shift invariant (LSI) systems: impulse response and step response; Response to an arbitrary input: convolution; system representation using differential and difference equations; Eigenfunctions of LTI/ LSI systems, frequency response and its relation to the impulse response. Signal representation: signal space and orthogonal bases; Fourier series representation of continuous-time and discrete-time signals; continuous-time Fourier transform and its properties; Parseval's relation, time-bandwidth product; discrete-time Fourier transform and its properties; relations among various Fourier representations. Sampling: sampling theorem; aliasing; signal reconstruction: ideal interpolator, zero-order hold, first-order hold; discrete Fourier transform and its properties. Laplace transform and Z-transform: definition, region of convergence, properties; transform-domain analysis of LTI/LSI systems, system function: poles and zeros; stability.
Learning Outcomes	Complies with PLO 1b, 2a and 2b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. A.V. Oppenheim, A.S. Willsky and H.S. Nawab, Signals and Systems, 2nd Edition, 2006, Prentice Hall. 2. S. Haykin and B. V. Veen, Signals and Systems, 2nd Edition, 1998, John Wiley and Sons. **Reference Books:** 1. B. P. Lathi, Signal Processing and Linear Systems, 1998, Oxford University Press.

Course Number	**EE2103**
Course Credit	**2-0-2-3**
Course Title	**Electrical Machines-I**
Learning Mode	Lectures and Experiments
Learning Objectives	Complies with Program goals 1, 2 and 3a
Course Description	The course is designed to meet the requirements of B. Tech. The course aims at giving detail of construction, operation and modelling of transformer and DC machines. Transformer and DC machines will be discussed.
Course Outline	Principles of Electromechanical Energy Conversions: Introduction, Flow of Energy in Electromechanical devices, Energy in Magnetic Systems, Singly Excited System, Determination of Mechanical Force, Mechanical Energy, Torque Equation, Doubly Excited System, energy stored in magnetic field, Electromagnetic Torque, Generated EMF in Machines, Torque in Machines with Cylindrical air-gap, General classifications of Electrical Machines. DC Machines: DC Generator: Parts of generator, Armature Winding, coil pitch, back pitch, front pitch, Resultant pitch, commutator pitch, single layer winding, two layer winding, Multiplex winding, lap & wave winding, dummy coils, Types of generators, Equalizer connections, EMF & Torque Equation, total losses and efficiency, Armature reaction, Demagnetizing and Cross Magnetizing Effects, Compensating winding Commutation, Methods for Improving Commutation, Interpoles, Performance Characteristics of DC generators, Critical speed, Critical resistance, Parallel operation, DC Motor: Principle of Motor, comparison of generator and motor action, Back Emf, Power & torque, Shaft torque, Performance characteristics of DC Motors, Losses & efficiency, power stages, speed control of DC motors, Electric Braking, Necessity of a starter, three point & four-point starters, Starting of DC motors. Transformers: Construction and principle, Types & Classification, operation at no load and on load, vector diagrams, equivalent circuit, losses, efficiency and regulation, determination of regulation and efficiency by direct load test and indirect test methods, Sumpner's test, parallel operation, auto transformer, condition for maximum efficiency, all day efficiency. Star/star, Star/delta, Delta/delta, Delta/Star, delta/zigzag, terminal marking, Nomenclature, Vector diagram, Phase groups, Parallel operation of 3-phase Transformer, Scott connection, V-V connections, tertiary winding, Testing of transformers, Transients in transformers - voltage regulation - off load and on load tap changers, Introduction of harmonics in Transformer Laboratory: Open circuit and short circuit tests of a single-phase transformer, Load Test on a single phase transformer, Sumpner's Test, Speed Control of DC Shunt motor, Open circuit test and load characteristics of DC generator, Speed control and output characteristics of DC motor
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. S. Chapman "Electric Machinery Fundamentals" 4th edition, 2003, McGraw-Hill. 2. B. S. Guru and H. R. Hiziroglu "Electrical Machinery and Transformers" 3rd edition, 2003, Oxford University Press. **Reference Books:** 1. I. L. Kosow "Electrical Machinery and Transformers" 2 edition, 2003, Prentice- Hall of India Pvt. Ltd.. 2. R. K. Rajput "Electrical Machines" 3 edition, 2003, Laxmi Publications (P) Ltd. 3. M.G. Say and E. M. Pink "The performance and design of alternating current machines: transformers, three-phase induction motors and synchronous machines" *2002, CBS.* 4. A. E. Fitzgerald, K. Charles, and S. D. Umans "Electric machinery." 6th edition, 2017, McGraw Hill. 5. A.S. Langsdorf "Theory of Alternating Current Machinery", 2nd edition, 1984, McGraw Hill.

Course Number	**EC2201**
Course Credit	**3-0-2-4**
Course Title	**Digital Electronics**
Learning Mode	Lectures and Labs
Learning Objectives	Complies with Program Goal 1, 2 and 4
Course Description	The course deals with the fundamental concepts used in digital electronics, analyzing and designing of various combinational and sequential circuits, identifying the basic requirements for a design application with focus on a cost effective solution, understanding the digital signals, and developing skills for designing combinational and sequential logic circuits and their practical implementation on breadboard.
Course Outline	Introduction to digital circuits: Logic families (RTL, TTL, ECL and MOS), Integer and floating point representation. Logic gates representation and combinational circuit realization, Boolean functions and simplification. Karnaugh Maps and logic optimization. Macro level combinational circuits and their realization: Multiplexers, Code converters, Decoders, parity Generators, 7-segment display decoder; Digital Arithmetic Circuits: Adders, Subtractor, BCD adders. Introduction to sequential elements (Latches and Flip-flops) and sequential circuit design, State machines. Finite state machines and examples: shift registers and counters. Introduction to memory circuits: RAM, ROM, EEPROM Introduction to programmable and reconfigurable devices. Digital logic realization using programmable Logic devices. Laboratory: To set up circuits for Bipolar (RTL, DTL, TTL) and Unipolar (MOS, CMOS) Logic families, Logic Gate verification; Introduction to Combinational circuits, Realization of Decoder, Design and realization of a Multiplexer and Magnitude Comparator; Verification of basic Flip Flops using 74XXICS, Implementation of basic Latches, Asynchronous Counters, Synchronous Counters, Pattern Generation and Detection
Learning Outcomes	Complies with PLO 1b, 2a, 2b and 4a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. D. P. Leach, A. P. Malvino and G. Saha, Digital Principal and Applications, 2nd Edition, 2006, McGraw-Hill. 2. J. F. Wakerly, Digital Design Principles and Practices, 4th Edition, 2006, Pearson Education. 3. M. Mano and M. D. Ciletti, Digital Design, 4th Edition, 2008, Pearson Education. 4. C. H. Roth, Fundamentals of Logic Design, 5th Edition, 2004, Cengage Learning. 5. N. Wirth, Digital Circuit Design: An Introductory Textbook, 1st Edition, 1995, Springer. 6. D. P. Leach, A. P. Malvino and G. Saha, Digital Principal and Applications, 2nd Edition, 2006, McGraw-Hill. **Reference Books:** 1. D. J. Corner, Digital Logic and State Machine Design, 3rd Edition, 2012, Oxford University Press. 2. H. Taub and D. Schilling, Digital Integrated Electronics, Illustrated Edition, 1977, McGraw-Hill.

Course Number	**EC2202**
Course Credit	**2-0-2-3**
Course Title	**Microprocessor**
Learning Mode	Lectures and Labs
Learning Objectives	Complies with Program Goal 1, 2 and 4
Course Description	The course deals with architecture & organization of 8085 & 8086 Microprocessor, classification of the instruction set of 8086 microprocessor and distinguishing the use of different instructions and applying it in assembly language programming. It also focuses on realization of the Interfacing of memory & various I/O devices with 8086 Microprocessor, familiarization of the architecture and operation of Programmable Interface Devices and realization of the programming & interfacing of it with 8086 Microprocessor. The course covers hands on experiments on emulator and hardware kits and give exposure to advanced microprocessor architectures.
Course Outline	Introduction to Microprocessor and Microcomputer, Introduction to 8-bit microprocessor: Internal architecture of Intel 8085 microprocessor Introduction to 8086: Block diagram, Registers, Internal Bus Organization, Functional details of pins, Control signals, External Address / Data bus multiplexing, Demultiplexing. 8086 Architecture: Addressing Modes, Instruction Set Architecture, Instruction Coding Format, Instruction Description and Assembler directives, Standard program Structure, Assembly Language Programming, Strings, Procedures, Macros,. Pinouts: minimum mode and maximum mode configurations, Bus structure, bus buffering, latching, system bus timing with diagram, Interrupt Controller. Timing, I/ O mapped I/ O, and memory mapped I/ O techniques. I/O and memory interfacing using 8086: Memory interfacing and I/O interfacing with 8086, Parallel communication interface (8255), Timer (8253 / 8254) , Keyboard / Display controller (8279), Priority Interrupt controller (8259) , DMA controller (8257). Coprocessor (8087) architecture and interfacing with 8086 Microprocessor Introduction to advanced Microprocessors (X86). <u>Laboratory:</u> Hands on laboratory experiment based on assembly language to program microprocessor using emulator/hardware kit to implement various algorithms and applications along with peripherals.
Learning Outcomes	Complies with PLO 1b, 2a, 2b and 4a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. R. S. Gaonkar, Microprocessor – Architecture, Programming and Applications with the 8085, 6th Edition, 2013, Penram International Publisher. 2. D. V. Hall, Microprocessors and Interfacing, 2nd Edition, 2012, McGraw-Hill. **Reference Books:** 1. B. B. Brey, The INTEL Microprocessors – 8086 / 8088, 80186 / 80188, 80286, 80386, 80486 Pentium and Pentium pro processor, Pentium II, Pentium III and Pentium IV - Architecture, Programming and Interfacing, 8th Edition, 2012, Pearson Education.

Course Number	**EE2201**
Course Credit	**3-0-2-4**
Course Title	**Control Systems**
Learning Mode	Lectures and Experiments
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	This course gives the idea of classical methods of Control Systems to be useful in Engineering applications. The prerequisite for this course is signal and systems.

Course Outline	Basic concepts: Notion of feedback, open- and closed-loop systems; Modeling and representations of control systems: Ordinary differential equations, Transfer functions, Block diagrams, Signal flow graphs, State-space representations; Performance and stability: Time-domain analysis, Second-order systems, Characteristic-equation and roots, Routh-Hurwitz criteria; Frequency-domain techniques: Root-locus methods, Frequency responses, Bode-plots, Gain-margin and phase-margin, Nyquist plots; Compensator design: Proportional, PI and PID controllers, Lead-lag compensators; State-space concepts: Controllability, Observability, pole placement result, Minimal representations; Introduction to nonlinear control. Laboratory: To Study the DC Modular Servo System and to obtain the characteristics of the constituent components. Also, to set up a closed loop position control system and study the system performance; Controller design for position and velocity control of servo motors; Modeling and analysis of Magnetic Levitation System; Design a PD/PID controller for the Magnetic Levitation System; Determine the transfer function of black box from the Bode plot Level control of three/ four coupled tanks; Study and design of controller for Inverted Pendulum System; Introduction to Matlab and analysis of basic control theory in Matlab; Linearisation and Simulation of Nonlinear Ship Roll Dynamics Twin rotor control using PI/PID controller
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Text/References** 1. N. S. Nise, Control Systems Engineering, 4th edition, New York, John Wiley, 2003. (Indian edition) 2. G. Franklin, J.D. Powell and A. Emami-Naeini, Feedback Control of Dynamic Systems, Addison Wesley, 1986. 3. I. J. Nagrath and M. Gopal, Control System Engineering, 2nd Edn.Wiley Eastern, New Delhi, 1982. 4. C. L. Phillips and R.D. Harbour, Feedback Control Systems, Prentice Hall, 1985 5. B.C. Kuo, Automatic Control Systems, 4th Edn. Prentice Hall of India, New Delhi, 1985. 6. K. Ogata, Modern control systems. Prentice Hall, 1997.

Course Number	**EE2202**
Course Credit	**2-0-2-3**
Course Title	**Electrical Machines-II**
Learning Mode	Lectures and Experiments
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	The course is designed to meet the requirements of B. Tech. The course aims at giving detail of construction, operation and modelling of AC machines. Induction and synchronous machine will be discussed.
Course Outline	AC Armature Winding: Number of Phases & Phase spread, Concentric winding, Mush winding, Double layer winding, Integral slot, lap & wave winding, Fractional Slot winding, Concentrated & Distributed winding in machines Three Phase Induction Motor: Classification of AC motors, working principle, Synchronous Speed, speed of rotor field, slip, starting & running torque, torque-slip characteristics, Starting & maximum torque, Rotor emf, effect of change in voltage & frequency on torque, speed & slip, Measurement of Slip, No-load & blocked rotor test, equivalent circuit, Phasor diagram, Circle diagram, Effect of rotor resistance on performance of induction motor, Double cage squirrel cage I.M. and its equivalent circuit, Basic of D-Q Control, Synchronous Machines: Alternator: Introduction, Stationary armature, rotor, Armature winding, Damper winding, Distribution factor, Emf equation, Alternator on load, Synchronous reactance, Voltage regulation, Methods of Voltage regulation i.e. EMF method, MMF method, Potier Triangle method, Torque, Operations, Machine efficiency, Armature reaction and it’s compensation, Short circuit ratio, Effect of increase in excitation, Brushless excitation, Effect of change in torque and speed, Determination of Synchronous reactance, AIEE methods,

	Synchronizing & load sharing between two machines Operating characteristics, Load angle and Power flow equations, Capability curves, Two reaction model of Salient pole machines, Effect of unequal voltages & percentage impedance, Short circuit transients, single phase generators, Slip test for measurement of Xd and Xq, Sudden short circuit of Synchronous machine. Synchronous Motor: Methods of starting of synchronous motors, Different torques in Synchronous motor, Synchronous motor with different excitation, V-curve and inverted V-curve, Stability, Power developed by synchronous motor, Synchronous condenser, Synchronous phase modifiers. <u>Laboratory:</u> No load and blocked rotor tests on a three phase squirrel cage induction motor; Load Test on a three phase squirrel cage induction motor; Load Test on three phase slip induction motor with different rotor resistances; open circuit and short circuit tests of an alternator; Load test on a three phase alternator; Synchronization of three phase alternator with grid supply
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. S. Chapman "Electric Machinery Fundamentals" 4th edition, 2003, McGraw-Hill. 2. B. S. Guru and H. R. Hiziroglu "Electrical Machinery and Transformers" 3rd edition, 2003, Oxford University Press. **Reference Books:** 1. I. L. Kosow "Electrical Machinery and Transformers" 2 edition, 2003, Prentice- Hall of India Pvt. Ltd.. 2. R. K. Rajput "Electrical Machines" 3 edition, 2003, Laxmi Publications (P) Ltd. 3. M.G. Say and E. M. Pink "The performance and design of alternating current machines: transformers, three-phase induction motors and synchronous machines" *2002, CBS.* 4. A. E. Fitzgerald, K. Charles, and S. D. Umans "Electric machinery." 6th edition, 2017, McGraw Hill. 5. A.S. Langsdorf "Theory of Alternating Current Machinery", 2nd edition, 1984, McGraw Hill.

Course Number	**EC2204**
Course Credit	**3-0-0-3**
Course Title	**Internet of Things (IoT)**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 4
Course Description	The course deals with fundamental building blocks of the Internet of Things components and its underlying concepts. It also covers the design aspect of various IoT applications.
Course Outline	Motivation, Applications and Objectives of Internet of Things (IoT), Cyber-Physical Systems and Wireless Sensor Networks. Sensors and Actuators, Sensor Types, Sensor Characteristics, Actuator Types, Controlling IoT Devices. Radio Frequency Identification (RFID) Technology, Connectivity Protocols in IoT: Bluetooth Low Energy, ZigBee, and LoRa. Data messaging Protocols in IoT: Message Queue Telemetry Transport (MQTT), Hyper-Text Transport Protocol (HTTP), Constrained Application Protocol (CoAP). Localization in IoT: Localization using Received Signal Strength (RSS), Time and Time difference of arrival (ToA/TdoA) and Angle based Localization. Sensor Fusion, Fog Computing and Edge Computing, Task Offloading. Security in IoT Networks. Use Cases of IoT for Smart Environments: Healthcare, Agriculture, and Smart City
Learning Outcomes	Complies with PLO 1b, 2a and 2b

Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. Raj, P., and Raman A.C., The Internet of Things: Enabling Technologies, Platforms, and Use Cases, 1st Edition, 2017, Auerbach Publications. 2. Rayes, A., and Salam, S., Internet of Things from Hype to Reality: The Road to Digitization, 2nd Edition, 2018, Springer. 3. Kumar S., Fundamentals of Internet of Things, 1st Edition, 2021, CRC Press. **Reference Books:** 1. Song H. et al., Cyber-Physical Systems: Foundations, Principles and Applications, 1st Edition, 2016, Academic Press Inc. **2.** Yan, L., et al., The Internet of Things: From RFID to the Next-Generation Pervasive Networked Systems, 1st Edition, 2008, CRC Press. **3.** Waher, P. , Learning Internet of Things, 2015, Packt Publishing Ltd.

Course Number	**EC3101**
Course Credit	**3-0-2-4**
Course Title	**Microcontroller and Embedded Systems**
Learning Mode	Lectures and Labs
Learning Objectives	Complies with Program Goal 1, 2 and 4
Course Description	The course deals with the fundamentals as well as advanced concepts in microcontroller and embedded systems. This also focuses on writing assembly and high level programs on real-time microcontrollers, developing the optimized embedded systems, and applying the ideas in different applications. Further it covers hands on experiments on commercially available embedded kits and components.
Course Outline	Introduction to microcontroller and embedded system, Introduction to CISC and RISC microcontroller, Registers, Pin diagram, I/O ports functions, 16-bits microcontroller architecture, Addressing modes, Internal memory organization, External memory (ROM & RAM) interfacing. Instruction set Architecture Data Transfer instructions, Arithmetic instructions, Logical instructions, Branch instructions, Bit manipulation instructions. Peripherals: Timers and Counters, PWM, Interrupts, communication protocols: UART, SPI. Embedded System Interfacing: ADC, DAC, Sensors, Display, keyboard. Embedded system models and development cycle, Embedded system components, Embedded processor and memory architecture. Hierarchical state machine, Embedded OS and RTOS, Scheduling, Multi-tasking. Experiments on microcontrollers: Programming and interfacing. **Lab**: PIC Microcontroller-Based Experiments: Write and implement a program to read input through a momentary switch and toggle the ON/OFF of led blinking; Write and implement a program to realize a simple calculator; Write and implement a program to generate precise delay and pulse by using TIMER; Write and implement a program to interface a seven segment display and scroll the roll number on single/multiple seven segment display; Write and implement a program to interface both keyboard and LCD display; Write and implement a program to interface a ADC peripheral and control LED brightness depending on ADC value; Write and implement a program to interface 16×2 LCD display and display the ADC value; Write and implement a program to use microcontroller as function generator and interface DAC to display generated signals in DSO; Write and implement a program to generate PWM and controlling a lightweight DC Motor; Write and implement a program to control speed and direction of the stepper Motor and use it as Clock. Arduino/Raspberry-Pi/Galileo-based Experiments: Write and implement a program to interface I2C IMU sensor and display over LCD display; Write and implement a program to interface blue tooth and Wi-Fi Devices
Learning Outcomes	Complies with PLO 1b, 2a and 2b

Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. M. A. Mazidi, R. D. McKinlay, D. Causey, PIC Microcontroller and Embedded Systems, 1st Edition, 2008, Pearson Education. 2. P. Marvedel, Embedded System Design, 4th Edition, 2021, Springer. **Reference Books:** 1. R. Kamal, Embedded Systems: Architecture, Programming and Design, 3rd Edition, 2017, McGraw Hill.

Course Number	**EE3101**
Course Credit	**2-0-2-3**
Course Title	**Power Systems - I**
Learning Mode	Lectures and Experiments
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	The course is designed to meet the requirements of B. Tech. The course aims at giving detail of power systems, generation methods, transmission line modelling and distribution systems.
Course Outline	Introduction: Basic structure of power system; demand of electrical system – base load, peak load; controlling power balance between generator and load, advantages of interconnected system. Generation of Electrical Energy: Thermal power plant – general layout, turbines, alternators, excitation system, governing system, efficiency; Hydel power plant – typical layout, turbines, alternators; Nuclear power plant – principle of energy conversion, types of nuclear reactors; brief overview of renewable energy sources: Solar Energy, Wind Energy etc. Transmission of Electrical Energy: Evaluation of Transmission line parameters- types of conductors, representation of transmission line, inductance calculation of single/three phase lines, concept of GMD and GMR, transposition of lines, bundled conductors, skin effect, proximity effect, capacitance calculation of single/three phase lines, effect of earth on calculation of capacitance, line resistance, line conductance; Analysis of transmission lines – representation, short/medium/long transmission lines, nominal T/π network, ABCD parameters, surge impedance, Ferranti effect, power flow through a transmission line, reactive power compensation of transmission line; corona loss; Insulators for overhead transmission lines – types of insulators, string efficiency, methods to improve string efficiency; Insulated cables – insulating material, grading of cables, capacitance of single/three core cable, dielectric loss; methods of grounding; Transient analysis – travelling waves, reflection and refraction, lattice diagram; mechanical design of transmission line. Distribution of Electrical Energy: D.C. and A.C. distribution, radial and ring main distribution, medium voltage distribution network, low voltage distribution network, single line diagram, substation layout, substation equipment Laboratory: Transmission Line Parameters; Transmission Line Modeling; Transmission Line Performance
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments, Lab, and Exams

Suggested Reading	<u>**Text/References**</u> 1. J. D. Glover, M. S. Sarma and T. J. Overbye, Power System Analysis and Design, 4/e, Thomson Learning Inc., 2007. 2. J. J. Grainger and W. D. Stevenson, Jr., Power System Analysis, Tata McGraw-Hill, 2003. 3. H. Saadat, Power System Analysis, Tata Mc-Graw Hill, 2002. 4. P. Kundur, Power System Stability and Control, Tata McGraw-Hill Edition, 2009. 5. J. Green and R. Wolson, Control and Automation of Electric Power Distribution System, Taylor and Francis, 2006. 6. T. Gonen, Electric Power Distribution System, McGraw-Hill, 1986. 7. S. N. Singh: Electric Power Generation, Transmission and Distribution, Prentice-Hall, 2007 8. D. P. Kothari, I. J. Nagrath, R. K. Saket "Modern Power System Analysis" McGraw Hill, 2022

Course Number	**EE3102**
Course Credit	**3-0-2-4**
Course Title	**Modern Control Theory**
Learning Mode	Lectures and Experiments
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	This course focuses on providing the knowledge of modern control theory. With the laboratory components, the course further attempts to provide the skill for implementing the control theories taught in the class for addressing real-life problems. The scope of this covers both linear and nonlinear systems.
Course Outline	State Variable Approach: Derivation of state model of linear time invariant (LTI) continuous systems, transfer function from ordinary differential equations, canonical variable diagonalization, system analysis by transfer function and state space methods for continuous systems convolution integral; State transition matrices and solution of state equations for continuous and discrete time systems. Discrete Systems: Introduction to discrete time systems, sample and hold circuits, pulse transfer function, representation by difference equations and its solution using z-transform and inverse z transforms, analysis of LTI systems, unit circle concepts; Stability criterion Controllability and Observability: Concept of controllability and observability, definitions, state and output controllability and observability tests for continuous and discrete systems, controllability and observability of time varying systems Introduction, effect of state feedback on controllability and observability, design via state feedback full order observer, reduced order observers design of state observers and controllers, pole placement, Ackerman's formula. Non-Linear Systems: Characteristics - different types of nonlinearities and their occurrence Phase plane analysis – Isocline, method - limit cycles in phase plane - stability of limit cycles – existence of limit cycle – Nonlinear feedback systems - Filter hypothesis - Describing functions - describing function for single valued and double valued nonlinear elements - amplitude and frequency of limit cycles. Stability of nonlinear Systems Linearization and equilibrium points - stability of equilibrium points - Lyapunov's First method - Stability of non-linear systems - Lyapunov method for nonlinear systems – Variable Gradient Method for generation of Lyapunov function. <u>Laboratory:</u> Discretization and its effect on linear systems; Observer design; SoC estimation; Study and analysis of limit cycle and phase portrait; Bifurcation analysis, Design of controller for various nonlinear systems: DOF helicopter/twin-rotor/inverted pendulum/ball beam balance/etc.
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments and Exams

Suggested Reading	**Text/References** 1. K. Ogata , “Modern Control Engineering”, 4th Ed., Pearson Education 2. I. J. Nagrath and M. Gopal, “Control System Engineering”, 5th Ed., New Age International Private Ltd. Publishers 3. B. C. Kuo, “Automatic Control Systems”, 8th Ed., Wiley India. 4. R. C. Dorf and R. H. Bishop, “Modern Control Systems” Pearson Education. 5. S. N. Norman , “Control Systems Engineering”, 4th Ed., Wiley India 6. K. P. Mohandas, Modern Control Engineering, Revised Edition, Sanguine Pearson, 2010. 7. H. K. Khalil, Nonlinear Systems, Prentice Hall International (UK), 1996.

Course Number	**EC3104**
Course Credit	**3-0-0-3**
Course Title	**Engineering Electromagnetics**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 4
Course Description	The course deals with frequency dependent circuit designs, and various aspects of wave propagation and mechanism. The focus would be on visualizing various field interactions and phenomena and hands-on with several electromagnetic simulators and components.
Course Outline	An overview of electrostatics, electromagnetic fields, and vector calculus. Time-varying EM fields: Maxwell’s equations, wave equation, and plane waves: Helmholtz wave equation, Solution to wave equations and plane waves, wave polarization, Poynting vector and power flow in EM fields. Wave Propagation: Wave propagations in unbounded & moving medium. boundary conditions, reflection, and refraction of plane waves. Transmission Lines: distributed parameter circuits, traveling and standing waves, impedance matching, Smith chart, stub matching. Introduction to antenna, Dipole antenna. Radio-wave propagation: ground-wave, sky-wave, and space-wave. Diversity techniques. Assignments on numerical methods using computational tools: FDTD, FEM.
Learning Outcomes	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. M. N. O. Sadiku, Elements of Electromagnetics, 3rd Edition, 2000, Oxford University Press. 2. R. F. Harrington, Time-Harmonic Electromagnetic Fields, 2nd Edition, 2001, Wiley-IEEE Press. 3. J. Griffiths, Introduction to Electrodynamics, 3rd Edition, 1999, Pearson Education. 4. E. C. Jordan and K. G. Balmain, Electromagnetic Waves and Radiating Systems, 2nd Edition, 2016, Pearson **Reference Books:** 1. K. E. Lonngren and S. V. Savov, Fundamentals Electromagnetics with MATLAB, 1st Edition, 2005, Pearson Education. 2. D. K. Cheng, Field and Wave Electromagnetics, 2nd Edition, 2001, Pearson Education. 3. N. Ida, Engineering Electromagnetics, 1st Edition, 2000, Springer. 4. W. H. Hayt Jr, J. A. Buck and M. J. Akhtar, Engineering Electromagnetics, 9th Edition, 2020, McGraw Hill.

Course Number	**EC3105**
Course Credit	**3-0-0-3**
Course Title	**Random Signals & Stochastic Processes**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 4
Course Description	The course deals with frequently encountered random variables, mathematical tools to analyze random process and development of analytical skills to model systems exhibiting random behavior
Course Outline	Random process: Concept of random process, ensemble, mathematical tools for studying random process, correlation function, stationarity, ergodicity, a few known stochastic processes: random walk, Poisson process, Gaussian random process, Markov chains, Brownian motion etc., pseudorandom process, nonlinear transformation of random process. Random process in frequency domain: Peridogram and power spectral density, Weiner-Khintchine-Einstein Theorem, concept of bandwidth, spectral estimation. Linear system: Discrete time and continuous time LTI system, concept of convolution, system described in frequency domain, state space description of the system. Linear systems with random inputs: Linear system fundamentals, response of a linear system, convolution, mean, autocorrelation and cross correlation function in LTI system, power spectral density in LTI, cross power spectral density in LTI. Processing of random signals: Noise in systems, noise bandwidth, SNR, bandlimited random process, noise reduction, matched filter, Wiener filter, Kalman filter, extended Kalman filter. Engineering examples.
Learning Outcomes	Complies with PLO 1b, 2a and 2b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Text/Reference Books:** 1. Miller, Scott, and Donald Childers, "Probability and random processes: with applications to signal processing and communications", Academic Press, 2012. 2. Wim C. van Etten, "Introduction to random signals and Noise", Chichester, England: Wiley, 2005. 3. Peyton Z. Peebles, "Probability, random variables, and random signal principles". McGraw Hill Book Company, 1987. 4. Geoffrey R. Grimmett, and David Stirzaker, "Probability and random processes", Oxford university press, 2001. 5. Alberto Leon-Garcia, "Probability, statistics, and random processes for Electrical engineering", Upper Saddle River, NJ: Pearson/Prentice Hall, 2008. 6. Grewal, Mohinder, and Angus P. Andrews, "Kalman filtering: theory and practice with MATLAB", John Wiley & Sons, 2014.

Course Number	**EE3201**
Course Credit	**3-0-2-4**
Course Title	**Fundamental of electric drives**
Learning Mode	Lectures and Experiments
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	The course is designed to meet the requirements of B. Tech. The course aims at giving detail of various electrical drives and analysis of them under various conditions.
Course Outline	Introduction to Electrical Drives, Dynamics of Electrical Drives, Review of Load Torque-Speed Characteristics of DC Motor Drives and Load, Solid-state Control of DC Motor Drives Controlled Rectifier-fed DC Drive, Chopper Controlled DC Drives, Synchronous link converter. Induction Motor Drives Operation of Induction Motor with Unbalanced Source Voltages Analysis of Induction Motor from Non-sinusoidal Voltage Supply Starting and Braking of Induction Motor Variable Voltage/ Current, Variable Frequency Control of Induction Motor Fed from VSI and CSI Control of Slip-ring Induction Motor, Kramer's and Scherbius Drives, Synchronous, Brushless DC Motor Drives, Stepper Motor and Switched Reluctance Motor Drives Laboratory: Chopper Based Control of DC Motor, Rectifier Based Control of DC Motor, Variable voltage and variable frequency Control of Induction Motor, Voltage control of Induction Motor, Inverter based Control of BLDC Motor, Control of Synchronous Motor, Control of Switched Reluctance Motor
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Text Books:** 1. G. K. Dubey "Fundamentals of electrical drives" 2nd edition, 2001, Alpha Science Int'l Ltd. 2. A. D. Veltman, W. J. Pulle, and R.W. D. Doncker. "Fundamentals of electrical drives" 2nd edition, 2016, Springer. **Reference Books:** 1. R. Ericson, D. Maksimovic, "Fundamentals of Power Electronics", 3rd edition, 2020, Springer. 2. I. Boldea, and S. A. Nasar. "Electric drives" 3rd edition, 2017, CRC press. 3. V. K. Yadav, R. K. Behera, Dheeraj Joshi, and Ramesh Bansal, "Power Electronics, Drives and Advanced Applications," 1st edition, 2020, CRC Press. 4. M Chilikin, "Electric Drives", 2nd edition, 1970, Mir Publishers.

Course Number	**EC3202**
Course Credit	**3-0-2-4**
Course Title	Digital Signal Processing
Learning Mode	Lectures and Labs
Learning Objectives	Complies with Program Goal 1, 2 and 4
Course Description	The course deals with the illustration of digital signals, systems and their significance. understanding of the analytical tools such as Fourier transforms, Discrete Fourier transforms, Fast Fourier Transforms and Z-Transforms required for digital signal processing. It also covers the design and development of the basic digital system, familiarization with various structures of IIR and FIR systems, design and realization of various digital filters for digital signal processing, interpretation of the finite word length effects on functioning of digital filters. Experimental concepts of DSP and its applications using MATLAB Software is also included.
Course Outline	Review of discrete time signals, systems and transforms and sampling theorems (bandlimited and bandpass signals) Discrete Fourier Transform (DFT): Computational problem, DFT relations, DFT properties, fast Fourier transform (FFT) algorithms (radix-2, decimation-in-time, decimation-in-frequency), Goertzel algorithm, linear convolution using DFT.

	Frequency selective filters: Ideal filter characteristics, lowpass, highpass, bandpass and bandstop filters, Paley-Wiener criterion, digital resonators, notch filters, comb filters, all-pass filters, inverse systems, minimum phase, maximum phase and mixed phase systems. Structures for discrete-time systems: Signal flow graph representation, basic structures for FIR and IIR systems (direct, parallel, cascade and polyphase forms), transposition theorem, ladder and lattice structures. Design of FIR and IIR filters: Design of FIR filters using windows, frequency sampling, Remez algorithm and least mean square error methods; Design of IIR filters using impulse invariance, bilinear transformation and frequency transformations. Laboratory ; DSK6713 Signal Processing Kit and MATLAB are used for the experiments: Familiarization with Kits and MATLAB, Linear and Circular Convolution, Z Transform, Discrete Fourier Transform & Fast Fourier Transform, IIR Filter Design – Analog Filter, Filter Design using Windowing Techniques
Learning Outcomes	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. S. K. Mitra, Digital Signal Processing: A computer-Based Approach, TMH, 2/e, 2001. 2. A. V. Oppenheim and R. W. Shafer, Discrete-Time Signal Processing, PHI, 2/e, 2004. 3. J. G. Proakis and D. G. Manolakis, Digital Signal Processing: Principles, Algorithms and Applications, PHI, 1997 4. TMS320C6XXX CPU and Instruction Set Reference Guide, Texas Instruments, 2000 (www.ti.com) 5. V. K. Ingle and J. G. Proakis, Digital signal processing using MATLAB, Thompson Brooks/Cole, Singapore, 2007. 6. MATLAB and Signal Processing Toolbox User's Guide (www.mathworks.com) **Reference Books:** 1. L. R. Rabiner and B. Gold, Theory and Application of Digital Signal Processing, Prentice Hall India, 2005. 2. A. Antoniou, Digital Filters: Analysis, Design and Applications, Tata McGraw-Hill, New Delhi, 2003.

Course Number	**EC3203**
Course Credit	**3-0-0-3**
Course Title	**Introduction to AI/ ML**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1,2 and 4
Course Description	The course deals with the comprehension of AI to analyze and map real world problem. and identification of electrical engineering problems (communication, power, control, signal processing) that is solved by AI techniques. It also focuses on different learning techniques and program/code in AI languages
Course Outline	Introduction: Foundations of Artificial Intelligence, Definitions; Problem solving: Problem-Solving Agents, Searching for Solutions, Uninformed Search, Breadth-first search, Depth-first search, Heuristic Search, Domain Relaxations, Local Search, Adversarial Search, Greedy best-first search; Logic and reasoning: Knowledge-Based systems, Propositional Logic, Reasoning Patterns in Propositional Logic, Resolution, Forward and Backward chaining, Syntax and Semantics of First-Order Logic, Using First-Order Logic, Propositional vs. First-Order Inference, Unification and Lifting, Forward Chaining, Backward Chaining, Resolution; Machine Learning: KNN, SVM, PCA, ICA, Clustering and ANN algorithms. Applications of AI in healthcare, communication, speech processing, electrical power and control engineering

Learning Outcomes	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. Patrick Henry Winston, *Artificial Intelligence*, Third Edition, Addison-Wesley Publishing Company, 2004. 2. Nils J Nilsson, *Principles of Artificial Intelligence*, Illustrated Reprint Edition, Springer Heidelberg, 2014 3. Duda, Richard O., and Peter E. Hart. *Pattern classification*. John Wiley & Sons, 2006 **Reference Books:** 1. Stuart Russell and Peter Norvig, *Artificial Intelligence: A Modern Approach*, 3rd Edition, PHI 2009.

Course Number	**EE3202**
Course Credit	**3-0-2-4**
Course Title	**Power Systems - II**
Learning Mode	Lectures and Experiments
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	The course is designed to meet the requirements of B. Tech. The course aims at giving detail of analysis of power systems in steady state and faulted conditions. Economics of power systems is also discussed.
Course Outline	Power System Analysis: Integrated operation of power systems, modeling of power system components, load flow studies, economic load dispatch, load frequency control, automatic generation control (AGC), power system stability. Power System Protection: Symmetrical components, fault analysis, switchgear, fuses, circuit breakers and relays. Economics of Power Supply Systems: Economic choice of conductor size and voltage level, maximum demand and diversity factor, tariffs, power factor correction. Special Topics: Introduction to high voltage DC transmission (HVDC), flexible AC transmission system (FACTS), supervisory control and data acquisition (SCADA). Laboratory: Formation of network matrices; Load Flow Analysis; Economic Dispatch; Automatic Generation Control; Power System Stability
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Texts & References** 1. D. P. Kothari and I. J. Nagrath, R. K. Saket, *Modern Power System Analysis*, McGraw-Hill, 2022. 2. P. Kundur, *Power System Stability and Control*, McGraw-Hill, 1995. 3. N. G. Hingorani and L. Gyugyi, *Understanding FACTS*, Wiley-IEEE Press, 1999. 4. J. Arrillaga, *High voltage direct current transmission*, IEE Power Engineering Series, 2/e, 1998. 5. A. J. Wood and B. F. Wollenberg, *Power Generation Operation and Control*, John Wiley and Sons, 2/e, 1996. 6. A. Wright and C. Christopoulos, *Electrical Power system protection*, Chapman & Hall, 1993.

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Course Number	**EE3203**
Course Credit	**3-0-2-4**
Course Title	**Power Electronics**
Learning Mode	Lectures and Experiments
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	The course is designed to meet the requirements of B. Tech. The course aims at giving detail of power semiconductor devices, rectifiers, dc-dc converters, and inverters.
Course Outline	Power semiconductor devices: structure and characteristics; snubber circuits, switching loss. Controlled rectifiers: full/half controlled converters for R, RL ,RLE load with source inductance and without source inductance, dual converters, sequence control. AC regulator circuits, reactive power compensators. dc-dc converters, switching dc power supplies. Inverters: square wave and PWM types, filters, inverters for induction heating and UPS. Wide Band Gap Devices, EMI and EMC. Laboratory: Rectifiers and applications; DC-DC Converters and applications; DC-AC Converters and applications; AC regulator circuits; Design of PWM generators and projects.
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Texts:** 1. N. Mohan: Power Electronics- Converters, Applications and Design, 3/e, 2003, John Wiley & Sons.. 2. G. K. Dubey: Fundamentals of Electrical Drives, 2003, Narosa Publishing House. **References:** 1. M. Rashid: Power Electronics- Circuits, Devices and Applications, 3/e, 2004, Prentice Hall. 2. B. K. Bose: Modern Power Electronics and AC Drives, 2003, Pearson Education. 3. A. M. Trzynadlowski: Introduction to Modern Power Electronics, 1998, John Wiley & Sons. 4. M. Rashid: Power Electronics Handbook, 2001, Academic Press-Elsevier.

Course Number	**EE3204**
Course Credit	**1-0-2-2**
Course Title	**Electrical Machine Design**
Learning Mode	Lectures and Experiments
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	The course is designed to meet the requirements of B. Tech. The course aims at giving design detail of electrical machines. A detailed design guidelines for transformer and rotating machine will be discussed.
Course Outline	Introduction: Design of Machines, Factors, limitations, Carter's coefficient, UMP, Axial and Radial duct, Modern trends. Materials: Conducting, magnetic and insulating materials. Magnetic Circuits: Calculations of mmf for air gap and teeth, real and apparent flux densities, iron losses, field form, leakage flux, specific permanence. Heating and Cooling: Modes of heat dissipation, Temperature gradients, types of enclosures, types of ventilation, conventional and direct cooling, amount of coolants used, Ratings. Armature Windings: Windings for DC and AC machines and their layout. Design of Transformers: Output equation, Types of transformer windings, design of core and windings and cooling tank, performance calculations. Concepts and Constraints in Design of Rotating Machines: Specific loading, output equation and output coefficient, effects of variation of linear dimension. Skeleton Design of Rotating Machines: Calculation of D and L for DC, induction and synchronous machines, length of air gap, design of field coils for DC and synchronous machines, selection of rotor slots of squirrel

	cage induction motors, design of bars and ends, design of rotor for wound rotor for induction motors, design of commutator and inter poles for DC machines. Computer Aided Design of Electrical Machines: Analysis and synthesis approaches, design algorithms, Introduction to optimization techniques, Implementing computer program for design of three phase induction motor, Introduction to Ansys Maxwell software for Electrical machine design
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. M. Ramamoorthy, "Computer Aided Design of Electrical Equipment" 2nd edition, 2008, East West Press Private Limited. 2. A.K. Sawhney, " A Course in Electrical Machine Design" 6th edition, 2017, Dhanpat Rai & CO. **References Books:** 1. M.G. Say and E. M. Pink. "The performance and design of alternating current machines: transformers, three-phase induction motors and synchronous machines" 2nd edition, 2002, CBS. 2. E. S. Hamdi, "Design of Small Electrical Machine" 1st edition, 1994, John Wiley and Sons. 3. S. P. Smith, and M. G. Say, "Electrical Engineering Design Manual" 2nd edition, 1984, Chapman and Hall.

Course Number	**EE4101**
Course Credit	**3-0-0-3**
Course Title	**Electric Traction and Propulsion**
Learning Mode	Lectures
Learning Objectives	Complies with Program goals 1, 2, 3 and 4
Course Description	The course is designed to meet the requirements of B. Tech. The course aims at giving an introduction to electric traction, traction systems and drives, and propulsion mechanism
Course Outline	Electric Traction Introduction, Traction Systems and Latest Trends, Mechanics of Train Movement, Traction Motors and Their Control, Electric Locomotives and Auxiliary Equipment, Feeding and Distribution System. Direct Drive Linear Motors and applications. Fundamentals of electric propulsion system including land, water and space, including space flight dynamics, rocket propulsion systems overview, nozzle theory, combustion processes, and flight performance.
Learning Outcomes	Complies with PLO 1b, 2b and 3b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Texts/References:** 1. Modern Electric Traction H. Partab Dhanpat Rai and Sons, New Delhi 2. Electric Traction J. Upadhyay S. N. Mahendra Allied Publishers Ltd., Dhanpat Rai and Sons, New Delhi 3. Electric Traction A.T. Dover Mac millan, Dhanpat Rai and Sons, New Delhi 4. Electric Traction Hand Book R. B. Brooks. Sir Isaac Pitman and sons ltd. London.

Course Number	**EE4102**
Course Credit	**3-0-0-3**
Course Title	**Power System Reliability**
Learning Mode	Lectures
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	The course is designed to meet the requirements of B. Tech. The course aims at giving reliability, application of probability distributions to evaluate the reliability of power systems.
Course Outline	Introduction to Reliability, Basic Probability Theory, Application of the binomial distribution, Network modelling and evaluation of simple systems, Network modelling and evaluation of complex systems, Probability distributions in reliability evaluation, System reliability evaluation using probability distributions, Distribution systems reliability-basic techniques and radial networks, Plant and Station availability.
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Texts/References:** 1. R. Billinton, R.N.Allan, BS Publications, Reliability Evaluation of Power systems, 2007. 2. J. Endrenyi, John Wiley and Sons,Reliability Modeling in Electric Power Systems, 1978

Course Number	**EC4101**
Course Credit	**3-0-0-3**
Course Title	**Introduction to Quantum Computing**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with the key components and architecture of quantum computing systems, including qubits, quantum gates, and quantum circuits. It also focuses on comprehending the principles of quantum information theory, including quantum entanglement, quantum entropy, and quantum teleportation. Implementation and analysis of quantum algorithms, such as Shor's algorithm for factoring and Grover's algorithm for search problems is also included.
Course Outline	Introduction: History, Motivation, Need of quantum bits, quantum states, quantum computations, quantum information, and quantum algorithms Overview of complex numbers and Linear Algebra, Introduction to quantum mechanics and its postulates, Bloch sphere Quantum gates: X, Z, Y, H, R, S, T, Square root of NOT Quantum Circuits: Single qubits and multiple qubits operations and quantum teleportation Quantum Algorithms: Deutsch's algorithm, Deutsch-Jozsa algorithm, Simon's algorithm Quantum Tools and Applications: Goal Challenges, Lights and Photon, Decoherence, Ion Trap, Quantum Simulation
Learning Outcomes	Complies with PLO 1b, 2a and 3a
Assessment Method	Quiz, Assignments and Exams

Suggested Reading	**Textbooks:** 1. Nielsen, M. A., and Chuang, I. L., Quantum computation and quantum information, 10th Anniversary Edition, 2010, Cambridge university press. 2. Yanofsky, N. S., and Mannucci, M. A., Quantum computing for computer scientists, 1st Edition, 2008, Cambridge University Press. **Reference Books:** 1. Johnston, E. R., Harrigan, N., and Gimeno-Segovia, M., Programming quantum computers: essential algorihms and code samples, 1st Edition, 2019, O'Reilly Media.

Course Number	**EC4102**
Course Credit	**3-0-0-3**
Course Title	**Deep Learning for Video Surveillance Systems**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with video surveillance tasks such as monitoring and processing of video footage, and understanding and analyzing of machine and deep learning models. The course also develop competence to take logical, scientific and correct decisions while predicting model outcomes. Aptitude and ability of performance measurement and management of video surveillance cameras is also covered.
Course Outline	Introduction to Video Surveillance Systems: Introduction to image processing methods, Edge detection and linking, Image transforms, Introduction to video processing techniques, Video compression standards. Motion detection using optical flow method, motion modeling, Background modeling, Basic building blocks of video surveillance systems. Introduction to Deep Learning: Introduction to neural networks with linear algebra, Matrix mathematics and probability, Introduction to multilayer perceptron networks, forward and back propagation, Hyper-parameter tuning, Regularization and optimization in neural networks, Introduction to tensor-flow. Convolutional Neural Nets: Introduction to convolutional neural networks, Key concepts like convolution and pooling. Stacking convolutional layers for object detection. Recurrent Neural Nets: Introduction to recurrent neural networks (RNN, LSTM, GRU) for sequence level tasks (time series, video). Bidirectional and deep recurrent nets. Use them for activity recognition. Object Detection and Classification using Deep Learning: Haar like feature based object detection, Viola Jones object detection framework, Deep learning based object classification. Object Tracking using Deep Learning: Video monitoring for detection and tracking of single as well as multiple interacting objects, Region-based tracking, Contourbased tracking, Feature-based tracking, Model-based tracking, KLT tracker, Meanshift based tracking. Deep Learning based Human Activity Recognition: Template based activity recognition, CNN based activity recognition, RNN based activity recognition, abnormal behavior detection in crowded environments using deep learning Camera Networks for Surveillance: Types of CCTV (closed circuit television) camera- PTZ (pan-tilt zoom) camera, IR (Infrared) camera, IP (Internet protocol) camera, wireless security camera, multiple view geometry, camera network calibration, PTZ camera calibration, camera placement, smart imagers and smart cameras, Introducing graph signal processing, consensus networks. Emerging Techniques of Deep Learning in Visual Surveillance System: Augmented surveillance system, Operator attention based visual surveillance system, EEG and eye tracking based visual surveillance system, ONVIF standard for the interface of IP-based physical security products.
Learning Outcomes	Complies with PLO 1b, 2a and 3b

Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. M H Kolekar, "Intelligent Video Surveillance Systems: An Algorithmic Approach", CRC press Taylor and Francis Group, 2018 2. Q. Huihuan, X. Wu, Y. Xu, "Intelligent Surveillance Systems", Springer Publication, 2011. 3. Ian Goodfellow, Yoshua Bengio and Aaron Courville, "Deep Learning", The MIT Press, 2017. **Reference Books:** 1. Murat A. Tekalp, "Digital Video Processing", Prentice Hall, 1995. 2. Pradeep K Atrey, Mohan Kankanhalli, A Cavallaro, "Intelligent Multimedia Surveillance: Current Trends and Research" Springer Publication, 2013. 3. Y. Ma and G. Qian (Ed.), "Intelligent Video Surveillance: Systems and Technology", CRC Press, 2009. 4. H. Aghajan and A. Cavallaro (Ed.), Multi-Camera Network: Principles and Applications", Elsevier, 2009.

Course Number	**EC4103**
Course Credit	**3-0-0-3**
Course Title	**FPGA based System Design**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with design of complex digital systems & use the design flow for using FPGA. This also gives exposure to Softcore Processor IP, Memory and other IO IPs and digital IPs, understanding of IP integration for large scale FPGA based digital System. Also, it covers performance analysis and issues of large scale digital system on FPGA and completion of a significant project on the FPGA platform.
Course Outline	Introduction to reconfigurable and FPGA based system Design; Basic and Advanced FPGA Fabrics; Combinational, Sequential logic and FSM realization on FPGA; FPGA Architecting: Speed, Area and Power; Issues on FPGA based system Design: Area, Timing and Power; Design Methodologies: Behavioral /high level Design and Implementation methodologies: RTL, IP Core, System Generator; Processor and memory cores; Timing analysis; Clock distribution and management systems; IP Cores for FPGA: Block and Distributed memory, FIFO, CORDIC, Clock distribution and management systems; Large scale System Design: Platform FPGA, Multi-FPGA System; Busses and I/O communication system; System Design and Implementation using FPGA: DSP and Communication Blocks and Cryptography blocks Introduction to FPGA based Embedded system platform: Soft processor, AHB Bus and I/O interfacing – Case studies.
Learning Outcomes	Complies with PLO 1b, 2b and 3b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Text/Reference Books:** 1. Wayne Wolf, "FPGA Based System Design", Prentice Hall Modern Semiconductor Design Series, 2004. 2. Steve Kilts, "Advanced FPGA design – Architecture, Implementation and Optimization", Wiley publications,2007. 3. Ron Sass and Andrew G. Schmidt, Morgan Kaufmann (MK), "Embedded System design with Platform FPGAs", Elsevier,2010.

Course Number	**EC4105**
Course Credit	**3-0-0-3**
Course Title	**Digital Image Processing**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with the fundamental concepts of digital image processing, including filtering, transforms, morphology, colour and image analysis. It also covers the basic image processing algorithms in C or Matlab or Python and make ready the students for advanced version of the course.
Course Outline	Introduction to Digital Image Processing & Applications, Sampling, Quantization, Basic Relationship between Pixels, ImagingGeometry, Image Transforms, Image Enhancement, Image Restoration, Image Segmentation, Morphological Image Processing, Shape Representation and Description, Object Recognition and Image Understanding, Texture Image Analysis, Motion Picture Analysis, Image Data Compression.
Learning Outcomes	Complies with PLO 1b, 2a and 3b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. Rafael C. Gonzalez and Richard E. Woods, Digital Image Processing, Pearson 2. Anil K. Jain, Fundamentals of Digital Image Processing, Prentice Hall **Reference Books:** 1. Milan Sonka, Vaclav Hlavac and Roger Boyle, Image Processing, Analysis and Machine Vision, Springer

Course Number	**EE4201**
Course Credit	**3-0-0-3**
Course Title	**Power System Protection**
Learning Mode	Lectures
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	The course is designed to meet the requirements of B. Tech. The course aims at giving the necessity of protecting power system components. The course discusses protection of generators, transformers and transmission lines protection.
Course Outline	Introduction to Power System Protection: Need for protective schemes, Nature and Cause of Faults, Types of Faults, Effects of Faults, Fault Statistics, Zones of Protection, Primary and Backup Protection, Essential Qualities of Protection, Performance of Protective Relaying, Classification of Protective Relays, Automatic Reclosing, Current Transformers for protection, Voltage Transformers for Protection. Relay Construction and Operating Principles: Introduction, Electromechanical Relays, Static Relays – Merits and Demerits of Static Relays, Numerical Relays, Comparison between Electromechanical Relays and Numerical Relays. Overcurrent Protection: Introduction, Time – current Characteristics, Current Setting, Time Setting. Overcurrent Protective Schemes, Reverse Power or Directional Relay, Protection of Parallel Feeders, Protection of Ring Mains, Earth Fault and Phase Fault Protection, Combined Earth Fault and Phase Fault Protective Scheme, Phase Fault Protective Scheme, Directional Earth Fault Relay, Static Overcurrent Relays, Numerical Overcurrent Relays. Distance Protection: Introduction, Impedance Relay, Reactance Relay, Mho Relay, Angle Impedance Relay, Effect of Arc Resistance on the Performance of Distance Relays, Reach of Distance Relays. Effect of Power Surges (Power Swings) on Performance of Distance Relays, Effect of Line Length and Source Impedance on Performance of Distance Relays.

	Differential Protection: Introduction, Differential Relays, Simple Differential Protection, Percentage or Biased Differential Relay, Differential Protection of 3 Phase Circuits, Balanced (Opposed) Voltage Differential Protection. Rotating Machines Protection: Introduction, Protection of Generators. Transformer and Bus zone Protection: Introduction, Transformer Protection, Buszone Protection, Frame Leakage Protection. Protection against Overvoltage: Causes of Overvoltage, Lightning phenomena, Wave Shape of Voltage due to Lightning, Over Voltage due to Lightning, Klydonograph and Magnetic Link, Protection of Transmission Lines against Direct Lightning Strokes, Protection of Stations and Sub – Stations from Direct Strokes, Protection against Travelling Waves, Insulation Coordination, Basic Impulse Insulation Level (BIL).
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments, and Exams
Suggested Reading	**Text Books:** 1. B. Ram, D.N. Vishwakarma "Power System Protection and Switchgear" 2 nd Edition, 2017, McGraw Hill. 2. H. J. A. Ferrer, and E. O. Schweitzer, eds. "Modern solutions for protection, control, and monitoring of electric power systems" 1st edition, 2010, Schweitzer Engineering Laboratories. 3. B. Oza et al "Power System Protection and Switchgear" 1 st Edition, 2010, McGraw Hill. **Reference Books:** 1. Bhavesh et al "Protection and Switchgear" 1 st Edition, 2011, Oxford. 2. N. Veerappan S.R. Krishnamurthy "Power System Switchgear and Protection" 1 st Edition, 2009, S. Chand. 3. S. H. Horowitz, A. G. Phadke, and C. F. Henville "Power system relaying" 3rd edition, 2014, John Wiley & Sons.

Course Number	**EE4202**
Course Credit	**3-0-0-3**
Course Title	**Digital Control System**
Learning Mode	Lectures
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	The scope of digital systems is very wide in the modern engineering era. Therefore, it is necessary that the students are taught with the control tools for handling the digital systems. This course focuses on the same.
Course Outline	Introduction: Structure and examples of digital control systems; input signals. Sampling and Reconstruction of Signals: Zero-order hold (ZOH); D-A conversion; sampling theory; aliasing; choice of the sampling period. z-transform theory: z-transforms of standard discrete-time signals; properties of z-transform; inversion of z-transform; final value theorem. Modeling of Digital Control Systems: ADC model; DAC model; transfer function of ZOH; DAC; analog subsystem; ADC combination transfer function; systems with transport lag; closed-loop transfer function; analog disturbances in a digital system; steady-state error and error constants for different input signals. Stability of Digital Control Systems: stable z-domain pole locations; asymptotic stability; BIBO stability; internal stability Routh-Hurwitz stability criterion; Nyquist stability criterion; phase margin; gain margin. Digital Control System Design: z-Domain root locus; z-Domain digital control system design (z-Domain contours, proportional control design in z-domain); Digital implementation of analog controller design (differencing methods, pole-zero matching, bilinear transformation, empirical digital PID controller tuning); direct z-domain digital controller design; frequency response design; direct control design; finite settling time design. State Space Analysis of Discrete-time Systems: discrete-time state space equations; z-transform solution of discrete-time state equations; z-transfer function from state space equations; controllability and stabilizability; observability and detectability.

Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Text Books:** 1. M. S. Fadali and Antonio Visioli, Digital Control Engineering Analysis and Design. Academic Press (Elsevier), Third Edition, 2020. 2. C. L. Phillips, H. Troy Nagle, Aranya Chakrabortty, Digital Control System Analysis & Design, Pearson Prentice Hall, 2015. 3. B. C. Kuo, Digital Control Systems, Oxford University Press, 1992. **References:** 1. S. Monaco and D. Normand-Cyrot, Issues on nonlinear digital control. European Journal of Control, vol. 7, no. 2-3, pp. 160-177, 2001. 2. J. R. Leigh, Applied digital control: theory, design and implementation. Courier Dover Publications, 2006. 3. B. Wittenmark, K. E. Årzén, and K. J. Astrom, Computer control: An overview. International Federation of Automatic Control, 2002. 4. K. Warwick and D. Rees, Industrial digital control systems. IET, 1988.

Course Number	**EE4203**
Course Credit	**3-0-0-3**
Course Title	**Introduction to Energy Storage Techniques**
Learning Mode	Lectures
Learning Objectives	Complies with Program goals 1, 2, 3 and 4
Course Description	The course is designed to meet the requirements of B. Tech. The course aims at giving a brief of energy storage technique. Various storage technique such as Battery, Fuel Cell etc will be discussed.
Course Outline	Energy storage systems overview - Scope of energy storage, needs and opportunities in energy storage, Technology overview and key disciplines, comparison of time scale of storages and applications, Energy storage in the power and transportation sectors. Thermal storage system-heat pumps, hot water storage tank, solar thermal collector, application of phase change materials for heat storage-organic and inorganic materials, efficiencies, and economic evaluation of thermal energy storage systems. Chemical storage system- hydrogen, methane etc., concept of chemical storage of solar energy, application of chemical energy storage system, advantages and limitations of chemical energy storage, challenges, and future prospects of chemical storage systems. Electromagnetic storage systems - double layer capacitors with electrostatically charge storage, superconducting magnetic energy storage (SMES), concepts, advantages and limitations of electromagnetic energy storage systems, and future prospects of electromagnetic storage systems. Electrochemical storage system (a) Batteries-Working principle of battery, primary and secondary (flow) batteries, battery performance evaluation methods, major battery chemistries and their voltages- Li-ion battery& Metal hydride battery vs lead-acid battery. (b) Supercapacitors- Working principle of supercapacitor, types of supercapacitors, cycling and performance characteristics, difference between battery and supercapacitors, Introduction to Hybrid electrochemical supercapacitors. (c) Fuel cell: Operational principle of a fuel cell, types of fuel cells, hybrid fuel cell-battery systems, hybrid fuel cell-supercapacitor systems.
Learning Outcomes	Complies with PLO 1b, 2a, 2b, 4a, 4b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Text books:** 1. F. S. Barnes and J. G. Levine: Large Energy Storage Systems Handbook (Mechanical and Aerospace Engineering Series), 2011, CRC press. 2. R. Zito: Energy storage: A new approach, 2010, Wiley. **References:** 1. G. Pistoia, and L. Boryann, Behaviour of Lithium-Ion Batteries in Electric Vehicles: Battery Health, Performance, Safety, and Cost, 2018, Springer International Publishing AG. 2. R. A. Huggins: Energy storage, 2010, Springer Science & Business Media.

	3. P. Denholm, E. Ela, Brendan Kirby and Michael Milligan: The Role of Energy Storage with Renewable Electricity Generation, National Renewable Energy Laboratory (NREL) -a National Laboratory of the U.S. Department of Energy.

Course Number	**EE4204**
Course Credit	**3-0-0-3**
Course Title	**Special Electrical Machines**
Learning Mode	Lectures
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	The course is designed to meet the requirements of B. Tech. The course aims at giving a detail of special electrical machines. Synchronous reluctance motor, switched reluctance motor, stepping motor, PMSM, PMBLDC will be discussed.
Course Outline	STEPPING MOTORS: Constructional features, principle of operation, types, modes of excitation, Torque production in Variable Reluctance (VR) stepping motor, Static and Dynamic characteristics, Introduction to Drive circuits for stepper motor, suppressor circuits, Closed loop control of stepper motor- Applications. SWITCHED RELUCTANCE MOTORS: Principle of Operation, Constructional features, Torque equation, Power Semi-Conductor Switching Circuits, frequency of variation of inductance of each phase winding - Control circuits of SRM-Torque - Speed Characteristics, Microprocessor based control of SRM Drive, Applications. SYNCHRONOUS RELUCTANCE MOTORS: Constructional features: axial and radial air gap Motors. Operating principle, reluctance torque - Phasor diagram, Speed torque characteristics, Applications. PERMANENT MAGNET BRUSHLESS DC MOTORS: Commutation in DC motors, Electronic Commutation - Difference between mechanical and electronic commutators- Hall sensors, Optical sensors, Construction and principle of PM BLDC Motor, Torque and E.M.F equation, Torque-speed characteristics, Power Controllers-Drive Circuits, Applications. PERMANENT MAGNET SYNCHRONOUS MOTORS: Construction and types, Principle of operation, EMF and Torque equation, Phasor diagram Torque Speed Characteristics.
Learning Outcomes	Complies with PLO 1a, 1b, 2a, 2b and 4b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Text/Reference books:** 1. M., T. JE Brushless permanent-magnet and reluctance motor drives., 1989, Clarendon Press. 2. R. Krishnan, Permanent magnet synchronous and brushless DC motor drives, 2017, CRC press. 3. V. V. Athani, Stepper motors: fundamentals, applications and design, 1997, New Age International. 4. P. Acarnley, Stepping motors: a guide to theory and practice. No. 63., 2002, IET. 5. B. Bilgin, J. W. Jiang, and A. Emadi Switched reluctance motor drives: fundamentals to applications., 2018, Boca Raton, FL. 6. N. Bianchi, B. Cristian, and G. Bacco Synchronous Reluctance Machines: Analysis, Optimization and Applications. vol. 186., 2021, IET.

Course Number	**EE4205**
Course Credit	**3-0-0-3**
Course Title	**High Voltage Engineering**
Learning Mode	Lectures
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	This course provides students with a comprehensive understanding of high voltage engineering, including the principles of electric field stress control, insulation technology, and high voltage testing techniques. Emphasis is placed on real-world applications, safety protocols, and the design and maintenance of high voltage equipment and systems.

Course Outline	Electric Field Strength (Electric Stress) : Introduction, Importance of Electric Field Intensity in the dielectrics, Types of electric fields and degree of uniformity fields, Utilization of dielectric properties and stress control. Gaseous Dielectrics : Properties of atmospheric air, SF6 and vacuum, Development of electron avalanche, Breakdown mechanisms, Breakdown in uniform fields, Breakdown of gaseous dielectrics in weakly non-uniform fields. Properties of liquid and solid dielectrics : Classification and properties, permittivity and polarization, Insulation resistance, conductivity, losses in dielectrics, Partial breakdown phenomenon in dielectrics. Generation of High Test Voltages : Methods of generation of power frequency high test voltage, transformers in cascade, Resonance transformers, Generation of high DC voltage, Impulse voltage generator. Measurement of High voltage: Peak high voltage measurement techniques, Sphere gap; Construction; Effects of earthed objects and atmospheric conditions, Electrostatic Voltmeters, Principle and Construction, Potential Dividers, their types and applications.
Learning Outcomes	Complies with PLO 1a, 3a and 3b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Text/References:** 1. E. Kuffel, W. S. Zaengl, and J. Kuffel, *'High Voltage Engineering Fundamentals'*, Butterworth-Heineman press, Oxford, 2000. 2. M. S. Naidu & V. Kamaraju, *High Voltage Engineering*, Tata McGraw Hill, 2004\

Course Number	**EE4206**
Course Credit	**3-0-0-3**
Course Title	**Fundamentals of Electric Vehicle Technology**
Learning Mode	Lectures
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	The course is designed to meet the requirements of B. Tech. The course aims at giving a brief overview of electric vehicle technology. Drive power train concept, inverter design, charger design and motor control will be discussed.
Course Outline	History of electric vehicle journey, Electric vehicle architecture and its type and challenges, Dynamics of electric vehicle, Benefits of using electric vehicle, Concept of drive cycle, Electric vehicle drivetrain components, Electric vehicle auxiliaries. 3-phase inverter design & analysis and its control, Multilevel inverter design & analysis and its control. Power factor correction AC-DC converter and its control, Phase -shifted full bridge converter and its control. Basics of Batteries, Lithium-ion vs Lead Acid Battery, Modelling of Battery, Supercapacitor, Fuel Cell. Introduction motor drive and its control, Permanent magnet motor drive and its control, Switched reluctance drive and its control.
Learning Outcomes	Complies with PLO 1a, 1b, 2a and 2b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**<u>Textbooks:</u>** 1. N. Mohan, T. M, Undelnad, W. P, Robbins: Power Electronics: Converters, Applications and Design, 3rd Edition, 2002, Wiley. 2. M. Eshani, Y. Gao, Sebastien E Gay, Ali Emadi: Modern electric, hybrid electric and fuel cell vehicles, Fundamentals, Theory, and Design. 2005, Boca Raton, FL, CRC. **<u>References:</u>** 1. R. Ericson Fundamentals of Power Electronics, 2004, Chapman & Hall. 2. F. A. Silva; M. P. Kazmierkowski: Energy Storage Systems for Electric Vehicles, 2021, MDPI.

Course Number	**EC4205**
Course Credit	**3-0-0-3**
Course Title	**Biomedical Signal Processing**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with.various Biomedical Signal Processing and Monitoring Tasks, analyzing machine and deep learning biomedical models. The course also develop competence to take logical, scientific and correct decisions while predicting model outcomes
Course Outline	**Introduction of biomedical signals**: Nervous system, Neuron anatomy, Basic Electrophysiology, Biomedical signal's origin and dynamic characteristics, biomedical signal acquisition and processing, Different transforms techniques. **The Electrical Activity of Heart**: Heart Rhythms, Components of ECG signal, Heart beat Morphologies, Noise and Artifacts, Muscle Noise Filtering, QRS Detection Algorithm, ECG compression techniques (Direct Time Domain (TP, AZTECH, CORTES, SAPA, Entropy Coding), Frequency Domain (DFT, DCT, DWT, KLT, Walsh Transform), Parameter Extraction: Heart rate variability, acquisition and RR Interval conditioning, Spectral analysis of heart rate variability. **The Electrical Activity of Brain**: Electroencephalogram, Types of artifacts and characteristics, Filtration techniques using FIR and IIR filters, Independent component analysis, Nonparametric and Model-based spectral analysis, Joint Time-Frequency Analysis, Event Related Potential, Noise reduction by Ensemble Averaging and Linear Filtering, Single-Trail Analysis and adaptive analysis using basis functions. **The Electrical Activity of Neuromuscular System**: Human muscular system, Electrical signals of motor unit and gross muscle, Electromyogram signal recording, analysis, EMG applications. **Frequency-Time Analysis of Bioelectric Signal and Wavelet Transform**: Frequency domain representations for biomedical Signals, Higher-order spectral analysis, correlation analysis, wavelet analysis: continuous wavelet transform, discrete wavelet transform, reconstruction, recursive multi resolution decomposition, causality analysis, nonlinear dynamics and chaos: fractal dimension, correlation dimension, Lyapunov exponent.
Learning Outcomes	Complies with PLO 1b, 2a and 3b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. Willis J. Tompkins, Biomedical Digital Signal Processing: C Language Examples and Laboratory Experiments for the IBM PC, Prentice Hall India 2. Eugene N. Bruce, Biomedical Signal Processing and Signal Modeling, John Wiley & Sons, 2006. 3. Rangaraj M. Rangayyan, Biomedical Signal Analysis: A Case-Study Approach, John Wiley & Sons, 2002 4. Steven J. Luck, An Introduction to the Event-Related Potential Technique, Second Edition, THE MIT PRESS 5. Leif Sornmo and Pablo Laguna, Bioelectrical Signal Processing in Cardiac and Neurological Applications, Academic Press, 2005 **Reference Books:** 1. Hojjat Adeli & Samanway Ghosh-Dastidar, Automated EEG based Diagnosis of Neurological Disorders, CRC Press. 2. Thomas P. Trappenberg, Fundamentals of Computational Neuroscience, Oxford University Press. 2002. 3. Mike X Cohen, Analyzing Neural Time Series Data Theory and Practice, THE MIT PRESS 4. Nait-Ali, Amine, Advanced Biosignal Processing, Spingers(Ed.). 2009

	5. C. Koch, Biophysics of Computation. Information Processing in Single Neurons, Oxford University Press: New York, Oxford 6. Peter Dayan and LF Abbott, Theoretical Neuroscience Computational and Mathematical Modeling of Neural Systems, MIT 2001. 7. F. Rieke and D. Warland and R. de Ruyter van Steveninck and W. Bialek, Spikes: Exploring the Neuronal Code, A Bradford Book. MIT Press.

Course Number	**EC4206**
Course Credit	**3-0-0-3**
Course Title	**High-Power Semiconductor Devices**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2, 3 and 4
Course Description	The course deals with the fundamental principles and physics of high-power semiconductor devices, analysing the performance characteristics and limitations of various high-power semiconductor devices, designing and simulating high-power semiconductor devices using advanced computational tools, assessing the impact of material properties and device architecture on the performance and reliability of high-power semiconductor devices, applying knowledge of high-power devices in the development of power electronic systems and evaluating the latest research and technological advancements in high-power semiconductor devices.
Course Outline	Introduction to High-Power Semiconductor Devices: Overview of high-power devices, Applications in power electronics Semiconductor Physics for High-Power Devices: Charge carrier dynamics, Breakdown mechanisms Power Diodes: Structure, operation, and types (e.g., Schottky, PiN), Performance characteristics and applications Power Bipolar Junction Transistors (BJTs): Structure and operation principles, High-power performance characteristics Insulated Gate Bipolar Transistors (IGBTs): Design and operation principles, Power MOSFETs: Structure, operation, and characteristics, Comparison with other high-power devices Thyristors and Related Devices: Structure and types (e.g., SCR, GTO), Switching characteristics and applications Thermal Management in High-Power Devices: Heat generation and dissipation, Thermal modeling and packaging techniques Reliability and Failure Mechanisms: Degradation and failure modes, Reliability testing and improvement strategies Advanced Materials for High-Power Devices: Wide bandgap materials (e.g., SiC, GaN), Advantages and challenges Integration and Application of High-Power Devices: Power modules and converters, Applications in renewable energy and electric vehicles Recent Advances and Research Trends: Innovations in high-power device technology,
Learning Outcomes	Complies with PLO 1a, 2a, 2b, 3a, and 4a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. B. Jayant Baliga, Power Semiconductor Devices, 1st Edition,Publisher: PWS Publishing Company, Year: 1995 2. B. Jayant Baliga, Fundamentals of Power Semiconductor Devices, 2nd Edition, Publisher: Springer, Year: 2010 **Reference Books:** 1. Josef Lutz, Heinrich Schlangenotto, Uwe Scheuermann, Rik De Doncker, Semiconductor Power Devices: Physics, Characteristics, Reliability, 2nd Edition, Publisher: Springer 2. Ned Mohan, Tore M. Undeland, William P. Robbins, Power Electronics: Converters, Applications, and Design, 3rd Edition, Publisher: Wiley, Year: 2002 3. B. Jayant Baliga, Wide Bandgap Semiconductor Power Devices: Materials, Physics, Design, and Applications, Publisher: Woodhead Publishing, Year: 2018

Course Number	**EC4207**
Course Credit	**3-0-0-3**
Course Title	**Biomedical Instrumentation**
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2, 3 and 4
Course Description	The course deals with the basic principles and functions of biomedical instruments, design and developing biomedical instruments for diagnostic and therapeutic purposes, analysing and interpreting data from biomedical instruments, applying knowledge of electronics, signal processing, and instrumentation in biomedical applications and addressing challenges in the design and application of biomedical instruments considering ethical and regulatory standards.
Course Outline	**Introduction to Biomedical Instrumentation:** Overview of biomedical engineering and instrumentation, History and evolution of biomedical devices, Types of biomedical instruments, Ethical and regulatory aspects in biomedical instrumentation **Biosignal Acquisition and Processing**: Types of biosignals (ECG, EEG, EMG), Basic transducer principles, Signal conditioning and processing techniques, Filtering and noise reduction **Biomedical Sensors and Measurement:** Types of biomedical sensors (e.g., temperature, pressure, flow sensors), Sensor characteristics and selection criteria, Measurement techniques and signal conditioning, Design principles Materials used in biomedical devices, Prototyping and testing **Diagnostic Instruments, Therapeutic and Prosthetic Devices:** Electrocardiographs (ECG), Electroencephalographs (EEG), Electromyographs (EMG), Imaging: X-ray, MRI, CT, Ultrasound; Pacemakers and defibrillators, Infusion pumps, Dialysis machines, Prosthetics and orthotics, Laser applications in medicine **Clinical Laboratory Instruments:** Blood gas analyzers, Hematology analyzers, Spectrophotometers Chromatography and electrophoresis, Immunoassay systems **Recent Advances in Biomedical Instrumentation:** Wearable health technology, Telemedicine and remote monitoring, Nanotechnology in medical devices Biomedical microelectromechanical systems (BioMEMS) Artificial intelligence and machine learning in biomedical instrumentation **Project and Case Studies:** Design and implementation of a biomedical device Case studies of biomedical instrumentation applications
Learning Outcomes	Complies with PLO 1a, 2a, 2b, 3a, 3b, 4a and 4b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. Webster, John G., ed. Medical instrumentation: Application and Design. John Wiley & Sons, 2009. 2. Carr, Joseph J., and John Michael Brown. Introduction to Biomedical Equipment technology. John Wiley & Sons, 1981. 3. Reddy, Narender P. "Book review: biomedical signal analysis: a case-study approach, by Rangaraja M. Rangayyan." Annals of Biomedical Engineering 30 (2002): 983-983. 4. Bronzino, Joseph D. Biomedical Engineering Handbook. Springer Science & Business Media, 2000. 5. Chatterjee, Shakti, and Aubert Miller. Biomedical Instrumentation Systems. Cengage Learning, 2012. 6. Khandpur, Raghbir Singh. Compendium of Biomedical Instrumentation, John Wiley & Sons, 2020. **Reference Books:** 1. Geddes, L.A., and Baker, L.E. "Principles of Applied Biomedical Instrumentation", Wiley-Interscience. 2. Carr, J.J., and Brown, J.M. "Introduction to Biomedical Equipment Technology", Pearson. 3. Pallás-Areny, R., and Webster, J.G. "Sensors and Signal Conditioning", John Wiley & Sons.