Department of Electrical Engineering						
Curriculum of M Tech Programme (Specialization: Power Electronics & Machine Drives)						
Sl. No.	**Subject Code**	**Name of the Subject**	**L**	**T**	**P**	**CP**
Semester I						
1	EE1011	ADVANCED POWER ELECTRONICS - I	3	1	0	4
2	EE1012	MACHINE DRIVES - I	3	1	0	4
3	EE1013	MACHINE ANALYSIS	3	1	0	4
4		ELECTIVE I	3	1	0	4
5		ELECTIVE II	3	1	0	4
6	EE1061	ADVANCED POWER ELECTRONICS LABORATORY	0	0	4	2
7	EE1062	COMPUTATION LABORATORY	0	0	4	2
Total Credit						**24**
Semester II						
1	EE2011	ADVANCED POWER ELECTRONICS - II	3	1	0	4
1	EE2012	MACHINE DRIVES - II	3	1	0	4
3	EE2013	ADVANCED CONTROL SYSTEMS	3	1	0	4
4		ELECTIVE III	3	1	0	4
5		ELECTIVE IV	3	0	0	3
6	EE2061	MACHINE DRIVES LABORATORY	0	0	4	2
7	EE2062	ADVANCED CONTROL LABORATORY	0	0	4	2
8	EE2063	PROJECT-I	0	0	2	1
Total Credit						**24**
Semester III						
1	EE3061	PROJECT–II				11
2	EE3062	PROJECT SEMINAR - I				2
Total Credit						13
Semester IV						
1	EE4061	PROJECT–III				11
2	EE4062	PROJECT SEMINAR - II & VIVA-VOCE				3
Total Credit						**14**
TOTAL						**75**

LIST OF ELECTIVES

Sl. No.	Subject Code	Name of the Subject
1	EE9011	POWER SYSTEM STABILITY
2	EE9012	POWER SYSTEM RELIABILITY
3	EE9013	DISTRIBUTED ENERGY SYSTEMS
4	EE9014	POWER SYSTEM OPTIMIZATION
5	EE9015	POWER SYSTEM MODELING
6	EE9016	SPECIAL ELECTRICAL MACHINES
7	EE9017	LINEAR CONTROL THEORY
8	EE9018	REAL TIME SYSTEMS DESIGN
9	EE9019	PROCESS INSTRUMENTATION & CONTROL
10	EE9020	ELECTRICAL VEHICLES
11	EE9021	MICROPROCESSOR BASED INDUSTRIAL CONTROL
12	EE9022	ROBOTICS & AUTOMATION
13	EE9023	INTELLIGENT CONTROL
14	EE9024	DIGITAL SIGNAL PROCESSING
15	EE9025	SOFT COMPUTING TECHNIQUES
16	EE9026	EMBEDDED SYSTEMS
17	EE9027	VLSI SYSTEMS
18	EE9028	BIOMEDICAL INSTRUMENTATION

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE1011	**Advanced Power Electronics - I**	**4 (3-1-0)**	**Prof. S. Banerjee and Dr. T. K. Saha**

Review of Power Electronic Systems, Overview of Some Modern Power Semiconductor Devices. [4]

Basic power electronic converters, Switch-Mode DC-DC Converters, Isolated Switching DC Power Supplies, Control Requirements & Techniques, Practical converter design considerations, Protection in converter circuits. [12]

Gate and Base Drive circuits for Power Devices, Introduction to Multilevel Converters [6]

Switch Mode Inverters, Different PWM techniques for Inverters: Space Vector PWM technique. [8]

Applications: DC Drives & AC Drives, Application in power systems, Other Residential and Industrial Applications: Electronic ballast, Induction Heating, Electrical Welding. [15]

Text Books:

1. Robert W. Erickson & D. Maksimovic, *Fundamentals of Power Electronics*, Kluwer Academic Publisher
2. N. Mohan, T. M. Underland & Riobbins, *Power Electronics: Converters, Applications & Design*, John-Wiley

Reference Books:

1. L. Umanand, *Power Electronics, Essentials & Applications,* Wiley India Pvt. Ltd.
2. E. Acha, V.G.Agelidis, O. Anaya-Lara and T.J.E.Miller, *Power Electronic Control in Electrical Systems*, Newnes
3. H. W. Whittington, Switch *Mode Power Supplies, Design and Construction,* Research Studies Press.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE1012	**MACHINE DRIVES-I**	**4 (3-1-0)**	**Mr. J. C. Barman**

Review of electric drive systems, electrical machines, power converters and control system. [2]

Different types of loads encountered in modern drive applications. [2]

Dynamics of drive systems, starting, braking, speed-control [3]

Closed loop dc motor drives – phase controlled and chopper controlled dc drives, controller design. [8]

Closed loop induction motor drives – Review of dynamic modelling of induction machine, space phasor model. [6]

Closed loop induction motor drives – V/f control, need for vector control. [4]

Basic structure and modeling of different electric drives and power converter [19]

Text Books:

1. Werner Leonhard, Control of Electrical Drives, 3rd edition, Springer 2001.
2. R. Krishnan, Electric Motor Drives: Modeling, Analysis, and Control, Prentice Hall, edition 1, 2001.

Reference Books:

1. Power Electronics and Motor Control – Shepherd, Hulley, Liang – II Edition, Cambridge University Press .
2. Control of Electric Machines and Drives System-Seung Ki Su-Wiley

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE1013	**MACHINE ANALYSIS**	**4 (3-1-0)**	**Dr. S. N. Mahato**

Generalized Machines:

Kron's primitive machine, Voltage, power and torque equations of Kron's primitive machine, Basic two-pole machine diagrams [5]

Reference Frame theory: Equations of transformation, 3-axis to 2-axis transformation, Park's transformation, Clarke's transformation, Stanley's equations. [4]

Theory of symmetrical Induction machines:

Voltage and torque equations in machine variables, dynamic modeling of three-phase induction machine, commonly used reference frames. [4]

Generalized model of three-phase induction machine in arbitrary reference frame, derivation of induction machine model in stator, rotor and synchronously rotating reference frames from the arbitrary reference frame model, steady-state equivalent circuit from dynamic equations. [6]

Dynamic performance during sudden change in load torque, per unit system, normalized model of induction machine, space-phasor model of induction machine, linearized equations of Induction machine, small-signal equations of induction machine, small displacement stability, eigenvalues. [8]

Synchronous Machines:

Stator and rotor flux linkages, Voltage and torque equations in machine variables, mathematical modeling of synchronous machine, Swing equation, state-space representation of Swing equation. [6]

DC machines:

DC generator: Motional inductance, steady-state analysis, transient analysis under different conditions. [6]

DC motor: Steady-state analysis, transient analysis under different conditions, sudden application of inertia load. [6]

Text Books:

1. Analysis of Electrical Machinery: P. C. Krause
2. Electric Motor Drives, Modelling Analysis and Control: R. Krishnan

Reference Books:

1. General Theory of Electrical Machines: Adkins
2. Modern Power Electronics and AC Drives: B. K. Bose
3. Generalized Theory of Electrical Machines: P. S. Bimbhra

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE1061	**Advanced Power Electronics Laboratory**	**2 (0-0-2)**	**Prof. S. Banerjee & Dr. T. K. Saha**

1. Microprocessor Based Single Phase Firing Angle Controller for AC-DC, AC-AC converter
2. Single Phase Bridge Inverter Using IGBT
3. Three Phase SCR Module for AC-DC, AC-AC converter
4. Speed Control of 3Ø AC Induction Motor Using IPM and MICRO–2407
5. DSP Based Induction Motor Control
6. Speed Control of DC Motor by Using Single Phase Triggering and Device module
7. Speed Control of DC Motor using SMPC and IPM
8. MOSFET Based Buck-Boost Converter and SMPS trainer
9. Four Quadrant Operation of DC-DC Chopper using IGBT
10. Simulation of Basic DC-DC Converters by Using Multisim/PSPICE
11. Modeling and control of Buck and Boost Converter by Using MATLAB

References:

1. Laboratory Manuals
2. PSpice and Multisim Manuals.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE1062	**Computation Laboratory**	**2 (0-0-2)**	**Dr. P. Acharjee**

1. Numerical solution of nonlinear equation, using Bisection Method/ Fixed point iteration/ Newton's method, by computer programming
2. (i) Numerical Solution of linear algebraic equations by computer programming using forwarding Gaussian elimination,
   (ii) Numerical Solution of linear algebraic equations by computer programming using Newton-Raphson method
3. (i) Numerical Integration by computer programming using trapezoidal rule/ Simpson's 1/3 rule
   (ii) Numerical solution of ordinary differential equations by computer programming using Runge-Kutta method
4. Power flow control with FACTS device (STATCOM) using differential evolutionary technique on MATLAB platform
5. Considering loss and cost, evaluate the economic load dispatch for IEEE test system using MATLAB.
6. Optimization of distributed systems based on some evolutionary techniques
7. Using artificial neural network, analysis L-G fault for IEEE 14-bus test system.
8. Considering practical security constraints, solve power flow using MiPower Simulation / MATLAB.

9. (i) Representation of a signal, analysis and processing of a continuous-time/discrete-time signal using signal processing toolbox in MATLAB
   (ii) Representation of a continuous-time/discrete-time system, Time domain analysis and response study, with MATLAB programming
10. (i) Study the behaviors of signals and systems in MATLAB/SIMULINK environment using especially "simpower" toolbox library

References:

1. Laboratory Manuals

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 2011	**Advanced Power Electronics - II**	**4 (3-1-0)**	**Prof. S. Banerjee**

Review of Switch Mode Power Converters [4]

Converter Dynamics and Control: State Space Averaging, Converter transfer function, concept of controller design, stability analysis, Non-linear phenomenon. [8]

Some advanced converters : Modeling & control of Tri-state, Interleaved, Multiphase & Higher order converters [6]

Multilevel Converters: fundamental topologies, Neutral Point Clamped (NPC), Flying Capacitor Converter, Cascaded Multilevel Converters, Other Multilevel voltage source inverters, applications. [8]

Advanced modulation techniques for Converters/Inverters; space vector modulation, carrier based modulation, Phase shifted multicarrier modulation, level shifted multicarrier modulation, third harmonic injection PWM. [6]

Resonant Converters: Classification of Resonant Converters, Series-Loaded and Parallel-Loaded Resonant Converter Topology, Soft Switching. [4]

Electromagnetic Interference (EMI) and Electromagnetic Compatibility (EMC) Issues: EMI reduction At Source, EMI Filters, EMI Screening, EMI Measurement and Specifications. [4]

Some practical applications, literature study, simulation and hands on training of power electronic converters. [5]

Text Books:

1. Robert W. Erickson & D. Maksimovic, *Fundamentals of Power Electronics*, Kluwer Academic Publisher
2. N. Mohan, T. M. Underland & Riobbins, *Power Electronics: Converters, Applications & Design*, John-Wiley

Reference Books:

1. E. Acha, V.G.Agelidis, O. Anaya-Lara and T.J.E.Miller, *Power Electronic Control in Electrical Systems*, Newnes
2. H. W. Whittington, Switch *Mode Power Supplies, Design and Construction,* Research Studies Press.
3. L. Umanand, Power *Electronics, Essentials & Applications,* Wiley India Pvt. Ltd

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 2012	**Machine Drives-Ii**	**4 (3-1-0)**	**Dr. S. N. Mahato & Dr. T. K. Saha**

Reference frame theory and transformation. : Three-phase transformations, a-b-c axis to d-q axis transformation, Space vectors and transformation. Dynamic analysis of three-phase Induction machine. Machine model in arbitrary d-q Reference frame, synchronously rotating reference frames, steady-state and transient model and simulation using MATLAB. [5]

Direct and Indirect Vector Control of Squirrel Cage Induction Machine (SQIM). Sensor less Vector Control of SQIM. [8]

Direct torque control (DTC) of SQIM [2]

Vector control of Wound Rotor Induction Machine. [4]

Control of Induction Generator. [4]

Synchronous machines:

Introduction, mathematical modelling, voltage and torque equations in machine variables, arbitrary reference frame variables and rotor reference variables, simulation of three-phase synchronous machines. [5]

Vector control of Permanent magnet synchronous machine, different control strategies, flux weakening operation, constant torque mode controller, flux weakening controller, sensorless control. [9]

Synchronous motor variable speed drives, variable frequency control of multiple synchronous motors, self-controlled synchronous motor drive using load-commutated thyristor inverter. [4]

Switched reluctance motor drives: Basic principle of operation, analysis, power electronics control of switched reluctance motor drives. [4]

Text Books:

1. Modern Power Electronics and AC Drives- B. K. Bose
2. Electric Motor Drives, Modelling Analysis and Control – R. Krishnan

Reference Books:

1. Advanced Electrical Drives- De Doncker, Rik, Pulle, Duco W.J., Veltman, André
2. Power Electronics and Variable Frequency Drives- B. K. Bose

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 2013	**Advanced Control systems**	**4 (3-1-0)**	**Prof. S. Banerjee & Dr. J. Dey**

Introduction

Sample Data System, The sampling process, Discrete-time signals and their classifications, Representation of discrete-time signals as sequences, Sampling Process; Sampling Theorem; Aliasing Sampling of Continuous-time signals, Signal reconstruction, Discrete-time Systems and their classifications, Finite dimensional LTI systems [5]

Difference equations, z -transform theory, z -transfer functions (pulse transfer functions), inverse z -transform and response of linear discrete systems, z -

transform analysis of sampled data control systems, *z* and *s* domain relationship[8]
Stability analysis in *z* -plane, Jury's stability criteria, Root Locus Analysis, Frequency Response of Sample data system, Bilinear Transformation, Bode diagram in w-plane [8]
Digital Controllers
Feedback Control, Classical Controller P, PI, PID, Lead and Lag [4]
State Space Representation of Discrete-time Systems:
State model state models for linear discrete time systems, conversion of state variables models to transfer functions in *z*-domain, solutions of state equations, state transition matrix, state transition flow graphs, eigenvalues, eigenvectors and stability similarity transformation, decompositions of transfer functions, canonical state variable models, controllability and observability, state feedback and pole placement, MATLAB tools and case studies [8]
Nonlinear Systems and Control:
Fundamentals of Nonlinear systems, dynamics, concept of stability and equilibrium point, domain of convergence, Lypunov stability, Jacobian matrix and stability, Phase plane analysis, describing function [12]

Text Books:

1. *Digital Control And State Variable Methods*, M. Gopal
2. *Discrete Time Control Systems*, K Ogata
3. *Nonlinear System*, H. K. Khalil

Reference Books:

1. *Digital Control System*, B. C. Kuo
2. *Digital Control Of Dynamic Systems*, G.Franklin, J.Powell, M.L. Workman.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 2061	**Machine Drives Laboratory**	**2 (0-0-4)**	**Dr. S. N. Mahato**

1. Speed control of three-phase induction motor using three level inverter and Micro 2812 DSP controller.
2. Speed control of three-phase induction motor using IPM and Micro 2812 DSP controller.
3. Speed control of three-phase induction motor using three level inverter and Micro 28335 DSP controller.
4. Speed control of three-phase induction motor using IPM and Micro 28335 DSP controller.
5. Speed control of BLDC motor using three level inverter and Micro 2812 DSP controller.
6. Speed control of BLDC motor using three level inverter and Micro 28335 DSP controller.
7. Speed control of BLDC motor using IPM and Micro 2812 DSP controller.
8. Speed control of BLDC motor using IPM and Micro 28335 DSP controller.

Reference:

1. Laboratory Manuals.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 2062	**Advanced Control Laboratory**	**2 (0-0-4)**	**Prof. S. Banerjee & Dr. J. Dey**

Hardware experiments:

Design and Real-time implementation of PID, LSVF & LQR controllers for

1. Digital Cart-inverted pendulum system
2. Digital Twin rotor MIMO system
3. Digital Magnetic levitation (MAGLAV) system
4. Digital Servo system

Software Experiments:

1. Design of a suitable controller for a given time delayed unity negative feedback closed loop system using root locus technique.
2. Design of lead, lag, lead-lag controller for a given unity negative feedback closed loop system using frequency domain design methods.
3. Design of linear quadratic optimal controller for a given continuous-time LTI plant.
4. Design of optimal state feedback controller for LTI plant where some of the states are not measurable.
5. Design of Kalman estimator when the sensors give noisy measurement for problem 3.
6. Design of H_∞ full information controller for a given LTI plant.
7. Design of digital controller using frequency domain design technique for a unity negative feedback closed loop system with a given continuous-time plant.

Reference:

1. Laboratory Manuals.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9011	**Power System Stability**	**4 (3-1-0)**	**Prof. S. P. Ghoshal and Prof. S. Ghosh**

Small Signal Stability: Small Signal stability of a single machine infinite bus system, Effects of excitation system, Power system stabilizer, Small-signal stability of multi machine systems and very large systems, Small-signal stability enhancement. [6]

Steady State Stability: Analysis of steady state stability of unregulated and regulated systems. [6]

Transient Stability: An elementary view of transient stability, Numerical integration methods, Simulation of power system dynamic response, Analysis of unbalanced faults, Performance of protective relaying, Case study of transient stability of a large system, Direct method of transient stability analysis, Transient stability enhancement. [10]

Voltage Stability: Basic concepts related to voltage stability, Voltage stability

analysis, Voltage collapse, Examples of Voltage collapse, Prevention of voltage collapse. [12]

Subsynchronous Oscillations: Turbine-generator torsional characteristics, Torsional interaction with power system controls, Subsynchronous resonance, Impact of network-switching disturbances, Torsional interaction between closely coupled units, Hydro generator torsional characteristics. [5]

Mid-term and Long-term Stability: Nature of system response to severe upsets, Distinction between mid-term and long-term stability, Power plant response during severe upsets, Simulation of long-term dynamic response, Case studies of severe system upsets. [6]

Text Books:

1. PrabhaKundur, Power System Stability and Control, TMH
2. P. M. Anderson & A. A. Fouad, Power System Control and Stability, IEEE Series on Power Engineering.

Reference Books:

1. Power Systems Stability, Vol. -1 – E. W. Kimbark, Dover Publications, New York.
2. Power Systems Stability, Vol. -2 – E. W. Kimbark, Dover Publications, New York.
3. Power Systems Stability, Vol. - 3 – E. W. Kimbark, Dover Publications, New York.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9012	**Power System Reliability**	**4 (3-1-0)**	**Prof. S. P. Ghoshal**

Fundamentals of probability and statistics [3]
Binomial, Poisson and normal distribution; [3]
Sampling theory [3]
General reliability function [1]
Exponential distribution [1]
Mean time to failure [3]
Markov processes [4]
Recursive techniques [6]
Loss of load probability method [2]
Load forecast uncertainty [3]
Loss of energy probability method [2]
Spinning capacity evaluation [4]
Derated capacity levels [3]
Transmission system reliability [4]
Interconnected system generating capacity reliability evaluation [3]

Text Books:

1. R. Billinton, Power System Reliability, Gordon & Breach

Reference Books:

1. M. Cepin, Assessment of Power System Reliability: Methods and Applications, Springer

2. A. A. Chowdhury and D. O. Koval, Power Distribution System Reliability, IEEE Press

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9013	**Distributed Energy Systems**	**4 (3-1-0)**	**Prof. N. K. Roy**

Evolution of world energy consumption, Nonrenewable and Renewable resources, Transformation of energy; [4]

Solar thermal, Solar radiation at the Earth's surface, Flat plate and concentrating type collectors, Solar energy storage, Solar pond, Solar heating and cooling techniques, Solar thermal power plant, Solar photo voltaic conversion, Solar cells, PV applications; [8]

Basic principles of wind energy conversion, Basic components of a Wind Energy Conversion System (WECS), classification of WECS, Details of wind turbine generator, Performance, Safety and Environmental aspects, applications; [5]

Classification of Small Hydro Power Plants, Components, Turbines and generators for small scale hydroelectric power plant Protection and control [4]

Geothermal Energy, Ocean Thermal Electric Conversion (OTEC), Tidal Power Generation, Fuel Cells, Magneto Hydro Dynamic (MHD) Power Generation, Thermo-electric power, Thermionic generation; [8]

Integration of renewable energy sources with the grid using Modern Power Electronics Technologies; Introduction to Distributed Generation & Intentional Islanding, Transient Analysis of Distributed Generators connected with grid, Micro-grid. [6]

Text Books:

1. G.D. Rai, Non-conventional energy resources, Khanna Publishers, New Delhi, 2003.
2. N. G. Clavert, Wind Power Principle, their application on small scale, Calvert Technical Press.

Reference Books:

1. Fuel Cell Handbook, Parsons Inc.
2. I. Earnest and T. Wizelius, Wind Power Plants and Projects development, PHI.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9014	**Power System Optimization**	**4 (3-1-0)**	**Prof. S. P. Ghoshal**

Economic Load Dispatch without losses and with losses; [4]

Optimal Power Flow applied to the solution of various IEEE systems, cost optimization, transmission loss optimization and total voltage deviation optimization, multi-objective optimization; [6]

Optimal Reactive Power Dispatch applied to the solution of various IEEE systems, [6]

Transmission loss optimization and total voltage deviation optimization and the combined optimization; [4]

Optimal load shedding; [4]
Optimal Hydrothermal Scheduling for short-range fixed head and variable head hydrothermal systems; multi-objective generation scheduling; [4]
Small Signal stability analysis based on various types of power system stabilizers; [4]
Optimal Automatic Generation Control, [8]
Optimal AVR control; [2]
Optimization of distributed systems; Evolutionary Programming. [3]

Text Books:

1. D.P. Kothari and J.S. Dhillon, *Power System Optimzation*, , Prentice Hall of India
2. J. A. Momoh, *Electric Power system Applications of Optimization*, CRC Press

Reference Books:

1. J. Zhu, *Optimization of power system operation*, John Wiley & Sons

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9015	**Power System Modeling**	**4 (3-1-0)**	**Dr. P. Acharjee**

Static Analysis and Model: background, motivation for modelling of physical systems, hybrid dynamic model, power system architecture. [4]
Network Model: lines and cables, transformers (single and three phase), series and shunt elements, load, generator. [6]
Formulation: network equations, equality and inequality constraints, active and reactive power flow with in-phase transformers and phase shifting transformers, decoupling properties, ac and DC power flow model. [5]
Fault analysis: transients on a transmission line, short circuit of a synchronous machine, generator model and Takahashi method for short circuit studies, examples. [5]
Power System Dynamics and Stability: power system stability, dynamics of power system and their modelling, examples. [5]
Synchronous Machine Models: Design and operating principle of rotor, stator and magnetic torque, stationary and dynamic operation of single phase equivalent circuit, phasor diagram, operational limits. [6]
Power Swings in a Simple Power System: swing equation and its solutions, qualitative analysis, stable and unstable solutions, equal area criterion, lyapunov stability, small signal analysis, oscillations in multi-machine systems. [6]
Control of Electric Power Systems: Control of Active Power and Frequency, Spinning reserve, Supplementary reserves, Back-Up Reserves; Control of Reactive Power and Voltage, Reactive Power Control Voltage; Control Supervisory Control of Electric Power Systems. [6]
Protections in Electric Power Systems: Design of Protections, Distance Protections, Out of Step Protections, System Protections. [4]

Text Books:

1. S. **Krishna**, "An Introduction to Modelling of Power System Components", springer, 2014.
2. Nasser D. Tleis, "Power Systems Modelling and Fault Analysis", Elsivier,

2008

Reference Books:

1. G¨oran Andersson, “Modelling and Analysis of Electric Power Systems”, ETH Z¨urich, 2008.
2. Mircea Eremia, Mohammad Shahidehpour, “Handbook of Electrical Power System Dynamics: Modeling, Stability, and Control”, Wiley-IEEE Press, 2013
3. Milano, Federico, “Power System Modelling and Scripting”, Springer, 2010.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9016	**Special Electrical Machines**	**4 (3-1-0)**	**Dr. S. N. Mahato**

STEPPER MOTORS: Constructional features, Principle of operation, Permanent magnet stepper motor, Variable reluctance motor, Hybrid motor, Single and multi-stack configurations, Torque equations, Modes of excitations, Characteristics, Drive circuits, Control of stepping motors. [10]

HIGH-SPEED OPERATION OF STEPPER-MOTORS: Pull-out torque/speed, characteristics of Hybrid stepper motors, calculation of pull-out torque, pull-out torque/speed characteristics for the VR stepper-motors, calculation of the pull out torque. [5]

SWITCHED RELUCTANCE MOTORS: Constructional features – Principle of operation – Torque production, Steady state performance prediction, Power Converters, Methods of Rotor position sensing, Closed loop control of SRM. [8]

BRUSHLESS D.C. MOTORS: Construction, Types, Principle of operation, Magnetic circuit analysis, Motor characteristics and control. [7]

PERMANENT MAGNET SYNCHRONOUS MOTORS: Principle of operation, EMF and Torque equations, Synchronous Reactance, Phasor diagram, Torque/speed characteristics, Power controllers, Converters, Control of motors. [7]

LINEAR INDUCTION AND SYNCHRONOUS MOTORS: Development of a Double-sided LIM from Rotary type IM, Schematic of LIM drive for electric traction, Development of one-sided LIM, Equivalent circuit of LIM, Linear Synchronous motor. [5]

SINGLE-PHASE SYNCHRONOUS MOTORS: Single Phase Reluctance and hysteresis motors. [3]

Text Books:

1. K. Venkataratnam, Special Electric Machines, Universities Press.
1. T. Kenjo and A. Sugawara, Stepping Motors and Their Microprocessor Controls, Claredon Press.

Reference Books:

1. T. Kenjo and S. Nagamori, Permanent Magnet and Brushless DC Motors, Claredon Press.
2. T.J.E. Miller, Brushless Permanent Magnet and Reluctance Motor Drives, Clarendon Press, Oxford, 1989.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9017	**Linear Control Theory**	**4 (3-1-0)**	**Prof. S. Banerjee & Dr. J. Dey**

Introduction [2]

Historical Perspective, Open loop Control, Development of Feedback/ Servomechanism/ Closed-loop Control

Dynamic System Representation [2]

Mathematical Modelling, Transfer Function/ matrix

Performance Objectives/ Goals [4]

Response and Loop Goals, Stabilization, Pole-placement, Tracking, Robustness, Disturbance Rejection, Noise Attenuation

Performance Analysis and Tests [4]

Time Domain Analysis, Internal Model Principle (IMP), Frequency Response analysis by bode diagram and Nyquist criterion, Loop Shaping Techniques, Sensitivity analysis, Utilities of Gain and Phase Margin determination

Compensation [4]

Feedforward Control, Feedback Control, Classical Controller P, PI, PID, Lead and Lag, One degree-of-freedom (1 DOF) control, Two DOF configuration, Linear State Variable Feedback (LSVF) control

State Space Representation of Continuous-time Systems [14]

State model state models for linear discrete time systems, conversion of state variables models to transfer functions in z-domain, solutions of state equations, state transition matrix, state transition flow graphs, eigenvalues, eigenvectors and stability similarity transformation, decompositions of transfer functions, canonical state variable models, controllability and observability, state feedback and pole placement, MATLAB tools and case studies

Robust and Optimal Control [15]

Linear Quadratic Regulator (LQR), Linear Quadratic Guassian (LQG), LQR with state estimator, Kalman filter/state estimator, Loop Transfer Recovery (LTR), H_2 and H_∞ control, Linear Matrix Inequality (LMI) technique

Text Books:

1. *Modern Control Engineering*, K. Ogata
2. *Feedback Control Theory*, John Doyle, Bruce Francis, Allen Tannenbaum
3. *Kalman Filtering Theory and Practice*, Mahinder S. Grewal and Angus P Andrews

Reference Books:

1. *Linear Control System Analysis And Design With MATLAB*, John J. D'Azzo and Constantine H. Houpis and Stuart N. Sheldon
2. *Linear Robust Control*, Michael Green and David J.N. Limebeer

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9018	**Real Time Systems Design**	**4 (3-1-0)**	**Dr. C. Koley**

Fundamentals of Real-Time Systems: History, Concepts, Definitions for Real-Time Systems, Diverse field of Applications, Modern Real-Time Systems [7]

Hardware for Real-Time Systems: Different microprocessor, classification, architecture, general feature, multi-core processors, Interfacing, memory, digital input and output, analog input and output. [7]

Memory Access and Layout Issues, Hierarchical Memory Organization, Pipelined Instruction Processing. [6]

Real-Time Operating Systems, Software Architecture, Round Robin- Round Robin with interrupts -Function Queue, Scheduling, Tasks and Task States -Tasks and

Data -Semaphores and Shared Data Message Queues -Mail Boxes and pipes -Timer Functions -Events -Memory Management, Interrupt Routines. [8]
Handling Resource sharing among real-time tasks, Priority, handling priority [5]
Scheduling Real-Time Tasks in Multiprocessor and Distributed systems, Introduction, system architecture design option. [5]
Real-Time Communication [4]
Real-Time Databases [4]

Text Books:

1. Real-Time Systems Design and Analysis: Tools for the Practitioner, 4th Edition, Phillip A. Laplante, Seppo J. Ovaska, Wiley-IEEE Press
2. Real-Time Systems: Design Principles for Distributed Embedded Applications, Authors: Kopetz, Hermann, Publisher: Springer, 2011

Reference Books:

1. Raj Kamal, *Embedded Systems Architecture*, Programming and Design, TMH
2. D. E. Simon, *An Embedded Software Primer*, Pearson Education

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9019	**Process Instrumentation and Control**	**4 (3-1-0)**	**Dr. C. Koley**

Measurement of Process Variables: Pressure, Flow, Temperature, Liquid Level, Strain, Force, Torque, Linear and angular displacement/speed etc.; [8]
Programmable Logic Controller (PLC): Introduction, Application, Physical and functional components, Timers, Counters, Shift Registers, Memory, Ladder Diagram, PLC Programming, Interfacing with sensors and actuators. Advance PLCs, analog input output, HMI, SCADA, Communication protocols, PID control through PLC; Data Acquisition Systems: Objective of a DAS, single channel DAS, Multi-channel DAS, Components used in DAS– Converter Characteristics-Resolution-Non-linearity, settling time, Monotonicity; [8]
Optical Fiber Based Instrumentation: General principles of optical fiber, brag grating fiber, amplitude modulating FO sensors, measurement of high current and voltage, temperature etc.; Power System Instrumentation: Measurement of Voltage, Current Frequency Phase and Transmission line Transients; [4]
Ultrasonic Instrumentation: Ultrasonic transmitter and receiver properties, propagation through medium and interfaces, application in Non-destructive Testing (NDT), measurement of process variables such as flow, level, thickness etc.; [5]
Digital Measurement Techniques and instrumentations: Different Digital Instrumentation, Digital Measurement of Power Factor, Frequency and Time Period, Counters; [3]
Recorders and Data Loggers: General Description, Measuring Parts and Recording Means; [3]
Microprocessor Based Instruments: Embedded systems, Microprocessor/Microcontrollers, classification, different field of application, design of microcontroller based measuring instrument. [4]
Industrial Process Control, ON-OFF Control, P, PI and PID control of interacting

and non-interacting process. [10]

Text Books:

1. A. D. Helfrick and William David Cooper, *Modern electronic instrumentation and measurement techniques*, Prentice Hall
2. John-G. Webster (ed.), *The Measurement, Instrumentation, and Sensors: Handbook*, Springer

Reference Books:

1. Curtis D. Johnson, *Process control instrumentation technology*, Prentice Hall
2. Robert N. Thurston and Allan D. Pierce, *Ultrasonic measurement methods*, Academic Press
3. William Bolton, *Programmable Logic Controllers*, Newness
4. Stuart A. Boyer, *Supervisory Control And Data Acquisition*, International Society of Automation
5. T. V. Kenneth and B. T. Meggitt, *Optical Fiber Sensor Technology*, Springer.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9020	**Electrical Vehicles**	**4 (3-1-0)**	**Mr. J. C. Barman**

Introduction to Hybrid Electric Vehicles: History of hybrid and electric vehicles, social and environmental importance of hybrid and electric vehicles, impact of modern drive-trains on energy supplies. [6]

Conventional Vehicles: Basics of vehicle performance, vehicle power source characterization, transmission characteristics, and mathematical models to describe vehicle performance. [6]

Hybrid-Electric vehicles: Concept and architecture of hybrid electric drive trains, series and parallel of hybrid electric drive trains, torque and speed coupling of hybrid electric drive trains. [6]

Electric Propulsion unit: Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives, Configuration and control of Induction Motor drives, configuration and control of Permanent Magnet Motor drives, Configuration and control of Switch Reluctance Motor drives, drive system efficiency [12]

Energy Storage: Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Super Capacitor based energy storage and its analysis, Flywheel based energy storage and its analysis, Hybridization of different energy storage devices. [8]

Sizing the drive system: Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor, sizing the power electronics, selecting the energy storage technology, Communications, supporting subsystems. [7]

Text Books:

1. Iqbal Husain, "*Electric and Hybrid Vehicles Design Fundamentals*" Published by: *CRC Press*, Boca Raton, Florida, USA, 2003.

Reference Books:

1. Chan, "*Modern Electric Vehicle Technology*", Oxford 2002

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9021	**Microprocessor Based Industrial Control**	**4 (3-1-0)**	**Dr. C. Koley**

INTRODUCTION: Block Diagram of a typical microprocessor based system pointing out the role of microprocessor and other peripheral blocks, functions; [4]
Microprocessor and Microcontroller: 68000, 8051, PIC16XXX, ARM controllers [8]
Interfacing I/O Devices I/O Controllers, Programmable Peripheral Devices, Interfacing, memory management; [4]
INTERFACING: Interfacing of Digital I/O Devices: Handshaking Logic, Programmed I/O, Interrupt driven I/O, Direct memory access, [3]
High Power Device Interfacing – Wave shaping, Driving and level shifting, Isolation; Interfacing of analog devices: [3]
D/A Converter (MC1408 8-bit D/A, DAC 1208 12-bit D/A), [2]
A/D Converter (ADC0808 8-bit ADC, ICL7109 12-bit ADC), Signal Conditioning; [2]
COMMUNICATION: Asynchronous serial data communication, Serial Data transmission methods and standards, USART, RS-232C Serial Data Standard, IEEE 488; [2]
MICROPROCESSOR BASED INDUSTRIAL SYSTEMS: Sensors: measurement of phase, frequency, power factor, temperature, flow, liquid level, pressure; [4]
Actuators: Mechanical and solid state Relays, AC Regulator, and Variable Frequency Drive; Controller: Digital ON-OFF and PID controller, [3]
PLC, DCS; Data Acquisition System: Functional block diagram, characteristics, and functions; Data Logger: Configuration, characteristics; Recorders: Functional block diagram, characteristics, and functions; [6]
APPLICATION OF MICROPROCESSOR BASED SYSTEM: PID control of electrical heater using solid state Relays, Speed Control of DC and Induction Motor, and Phasor Measurement Unit. [6]

Text Books:

1. Douglas V. Hall, *Microprocessors & Interfacing*, Tata McGraw-Hill
2. M. Predko, *Programming & Customising 8051 Microcontroller*, TMH

Reference Books:

1. John Uffenbeck, *Microcomputers and Microprocessors*, Pearson Education
2. Michel Slater, *Microprocessor Based Design*, PHI

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9022	**Robotics and Automation**	**4 (3-1-0)**	**Prof. S. Banerjee & Dr. J. Dey**

BASIC CONCEPTS: Definition and origin of robotics – different types of robotics – various generations of, robots – degrees of freedom – Asimov's laws of robotics – dynamic stabilization of, robots. [6]
POWER SOURCES AND SENSORS: Hydraulic, pneumatic and electric drives – determination of HP of motor and gearing ratio – variable speed arrangements – path determination – micro machines in robotics –machine vision – ranging – laser – acoustic – magnetic, fiber optic and tactile sensors. [8]

MANIPULATORS, ACTUATORS AND GRIPPERS: Construction of manipulators – manipulator dynamics and force control – electronic and pneumatic manipulator control circuits – end effectors – U various types of grippers –design considerations. [8]

KINEMATICS AND PATH PLANNING: Solution of inverse kinematics problem – multiple solution jacobian work envelop – hill climbing techniques – robot programming languages [8]

CONTROL SYSTEMS: The manipulator Control problem, Linear control schemes, Linear model of a manipulator joint, Joint actuators, PID control scheme, Computed torque control, Force control strategies, Hybrid position/force control architecture, Impedance force/torque control, Adaptive Control. [10]

CASE STUDIES: Mutiple robots – machine interface – robots in manufacturing and non- manufacturing applications – robot cell design – selection of robot. [5]

Text Books:

1. L. Sciavicco and B. Siciliano, *Modeling and Control of Robot Manipulators*, Springer
2. K. S. Fu, R. C. Gonzalez and C. S. G Lee, *Robotics: Control, Sensing, Vision, and Intelligence*, McGraw-Hill Inc.
3. Mikell P. Weiss G.M., Nagel R.N., Odraj N.G., Industrial Robotics, McGraw-Hill, Singapore, 1996.

Reference Books:

1. J. J. Craig, *Introduction to Robotics, Mechanics and Control*, Addison Wesley
2. R. J. Schilling, *Fundamentals of Robotics Analysis and Control*, Prentice Hall.
3. Deb.S.R., Robotics technology and flexible Automation, John Wiley, USA 1992.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9023	**Intelligent Control**	**4 (3-1-0)**	**Prof. S. Banerjee & Dr. J. Dey**

A challenge to automatic control, Definition of intelligent control, Advance in intelligent control, Structural theories of intelligent control, Research and applications of intelligent control, Methodology of Knowledge representation, General interference principles, Hierarchical control systems. [6]

Expert control systems; Mathematical foundation for fuzzy control, fuzzy logic, crisp sets and fuzzy sets, fuzzy set operations and approximate reasoning, Fuzzification, inferencing and defuzzification. Fuzzy knowledge and rule bases, Architecture of fuzzy controllers, Design of fuzzy controllers, properties of fuzzy controllers, Fuzzy modeling and control schemes for nonlinear systems, Self-organizing fuzzy logic control, Fuzzy logic control for nonlinear time-delay system, Implementation of fuzzy logic controller using Matlab Stability analysis of fuzzy control systems, applications. [15]

Concept of Artificial Neural Networks and its basic mathematical model, McCulloch-Pitts neuron model, simple perceptron, Adaline and Madaline, Feed-forward Multilayer Perceptron, Learning and Training the neural network, Data Processing, Fourier transformation, principal-component analysis and wavelet transformations ANN Networks: Hopfield network, Self-organizing network and

Recurrent network. Structural Schemes of neurocontrol systems, Neural Network based controller. [12]

Case studies: Identification and control of linear and nonlinear dynamic systems using Matlab, Stability analysis of Neural-Network interconnection systems, Integration of Fuzzy logic, NN and expert systems for control, Paradigms of NN-based control system; Basic concept of Genetic algorithm and detail algorithmic steps, adjustment of free parameters, Solution of typical control problems using genetic algorithm. Concept on some other search techniques like tabu search and ant-colony search techniques for solving optimization problems. [12]

Text Books:

1. Large-Scale Systems: Modeling, Control and Fuzzy Logic, Author:Mo Jamshidi (on line)
2. L. A. Zadeh, *Fuzzy Sets and Applications*, John Wiley & Sons
3. Simon Haykin, *Neural Networks: A Comprehensive Foundation*, Prentice Hall

Reference Books:

1. Jyh-Shing Roger Jang, Chuen-Tsai Sun & Eiji Mizutani, *Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence*, Prentice Hall
2. S. Rajasekaran and G. A. Vijayalakshmi Pai, Neural Networks, Fuzzy Logic and genetic Algorithm Synthesis and Applications, PHI
3. Intelligent Control Systems, Using Soft Computing Methodologies, Editors: Ali Zilouchian, Mo Jamshidi (on line).

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9024	**Digital Signal Processing**	**4 (3-1-0)**	**Prof. S. P. Ghoshal**

Discrete time signals and systems, properties, convolution, analysis of discrete time systems in time-domain; [4]

Frequency domain representation of discrete time systems and signals, Gibbs phenomenon, band limited signals, sampling theorem aliasing sampling of continuous time signals; [4]

Z- transforms, region of convergence, Z- transform theorems and properties, methods of Inverse Z-transforms, analysis of discrete time signals and systems in Z-domain, pole-zero plots, stability; [4]

Realization of FIR Systems and IIR systems; [6]

Discrete time Fourier transform of discrete time signals and systems, Inverse discrete time Fourier transform, Eigen function, [4]

Discrete Fourier transform (DFT), properties of DFT, Linear convolution using DFT, Computation of DFT by FFT algorithms like decimation in frequency and decimation in time; [6]

Various Filter design techniques for FIR and IIR filters; [8]

Sampling rate conversion, up rate and down rate sampling, interpolation and decimation; [3]

Introduction to discrete Hilbert Transform, Complex Capstrum, Application of Capstral analysis; [4]

Practical applications of DSP, DSP processors. [2]

Text Books:

1. J. G. Proakis & D. G. Manolakis, *Digital Signal Processing: Principles, Algorithms and Applications*, Prentice Hall of India.
2. E. Ifeachor & B.W. Jervis, *Digital Signal Processing, A practical Approach*, Pearson Education Ltd.

Reference Books:

1. S. K. Mitra, *Digital Signal Processing*, McGraw Hill Co. Inc.
2. S, Poornachandra & B. Sasikala, *Digital Signal Processing*, Tata McGraw-Hill Education Pvt. Ltd.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9025	**Soft Computing Techniques**	**4 (3-1-0)**	**Dr. P. Acharjee**

Introduction to soft-computing techniques and its necessity [1]

Fundamentals of genetic algorithm, Genetic algorithm, Encoding, Fitness function, Reproduction, Genetic modelling, Cross Over, Inversion and Deletion, Mutation operator, Bit-wise operators, examples. [1+3+2+1+1]

Basic Steps in Particle Swarm Optimization algorithm, Bird flocking & fish schooling, velocity, inertia weight factor, pbest solution, gbest solution, local optima, global optima, examples, new modifications of PSO, Parameter Selection in PSO. [1+2+2+2+1]

Fundamentals of Differential Evolution algorithm, difference vector and its significance, Mutation and crossover, comparisons among DE, PSO and GA, Examples, new modifications of DE, Improved DE schemes for noisy optimization problems. [1+1+2+1+2+1]

Fuzzy set theory, Fuzzy systems, crisp sets and fuzzy sets, fuzzy set operations and approximate reasoning, Fuzzification, inferencing and defuzzification, Fuzzy knowledge and rule bases, examples. [1+2+2+2+1]

Biological neural networks, Model of an artificial neuron, neural network architecture, Characteristics of neural network, learning methods, Taxonomy of neural network architecture, Back propagation networks, architecture of a back propagation network, back propagation learning, Examples, RBF network, Associative memory, Adaptive resonance theory. [1+1+2+2+2+1]

Applications of Soft Computing to various fields of engineering. [2]

Text Books:

1. Devendra K. Chaturvedi, “Soft Computing- techniques and its application in electrical engineering”, Springer, 2008.
2. Carlos A. Coello,Garry B. Lamont, David A. van Veldhuizen, “Evolutionary Algorithms for solving Multi-objective Problems”, Second Edition, Springer, 2007.

Reference Books:

1. Jyh-Shing Roger Jang, Chuen-Tsai Sun &EijiMizutani, Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence, Prentice Hall
2. S. Rajasekaran and G. A. VijayalakshmiPai, Neural Networks, Fuzzy Logic

and genetic Algorithm Synthesis and Applications, PHI
3. Simon Haykin, Neural Networks: A Comprehensive Foundation, Prentice Hall
4. L. A. Zadeh, Fuzzy Sets and Applications, John Wiley & Sons

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9026	**Embedded Systems**	**4 (3-1-0)**	**Dr. C. Koley**

Introduction to Embedded systems:
Introduction – Features – Microprocessors – ALU - Von Neumann and Harvard Architecture, Classification, SPP, ASIC, ASIP [4]
CISC and RISC - Instruction pipelining. Fixed point and Floating point processor[3]
General characteristics of embedded system, introduction to different components etc. [6]
Microcontroller 89CX51/52 Series: Characteristics and Features, Overview of architectures, and Peripherals, Timers, Counters, Serial communication, Digital I/O Ports. [4]
Microcontroller PIC Series: Characteristics and Features, Overview of architectures, and Peripherals, Interrupts, Timers, watch-dog timer, I/O port Expansion, analog-to-digital converter, UART, I2C and SPI Bus for Peripheral Chips, Accessories and special features. [5]
ARM Architecture: Evolution, Characteristics and Features, Overview of architectures, Modes, Registers etc [8]
Digital Signal Processor [4]
Software architecture and RTOS:
Software Architecture: Round Robin- Round Robin with interrupts -Function Queue. Scheduling
Architecture RTOS: Architecture -Tasks and Task States -Tasks and Data -Semaphores and Shared Data Message Queues -Mail Boxes and pipes -Timer Functions -Events -Memory Management, Interrupt Routines. [6]
Basic design using a real time operating system:
Overview. General principles. Design of an embedded system.
Development Tool: Cross-Compiler, Cross-Assemblers, Linker/locator. PROM Programmers, ROM, Emulator, In-Circuit Emulators. Debugging Techniques. Instruction set simulators. The assert macro. [6]

Text Books:

1. Raj Kamal, *Embedded Systems Architecture*, Programming and Design, TMH
2. D. E. Simon, *An Embedded Software Primer*, Pearson Education

Reference Books:

1. J. B. Peatman, *Design with PIC Microcontrollers*, Pearson Education

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9027	**VLSI Systems**	**4 (3-1-0)**	**Prof. S. P. Ghoshal**

Physics and Modelling of MOSFETS [4]
Fabrication and Layout of CMOS Integrated Circuits; [4]

The CMOS Inverter: Analysis and Design	[6]
Switching Properties of MOSFETS	[6]
Static Logic Gates;	[6]
Dynamic Logic Circuit Concepts	[6]
CMOS Dynamic Logic Families	[6]
CMOS Differential Logic Families	[6]
Issues in Chip Design	[4]

Text Books:

1. John P. Uyemura, *CMOS Logic Circuit Design*, Kluwer Academic Publishers

Reference Books:

1. Sung-Mo (Steve) Kang & Yusuf Leblebici, CMOS Digital Integrated Circuits Analysis and Design, McGraw-Hill Education
2. Christian Piguet, Low-Power CMOS Circuits, Technology, Logic Design and CAD Tools, Taylor & Francis.

SUBJECT CODE	SUBJECT NAME	CREDIT	DEVELOPER
EE 9028	**Biomedical Instrumentation**	**3 (3-0-0)**	**Dr. Suman Halder**

Organization of Cell, Cellular Constituents, Cellular Organelles, Cell Membrane Structure, Cellular Transport Processes [5]

Generation of Nernst Potential, Establishment of diffusion potential, Goldmann Equation, Measurement of membrane potential, resting potential, action potential, role of voltage gated channels for controlling action potentials. [5]

Role of sinus node for generation of ECG, ECG Transmission Process, Ectopic pacemakers, Analysis of ECG. [4]

Use of electrodes for measurement of biopotentials, polarization in electrodes, principle of operation of Ag/Agcl electrode, Equivalent circuit of electrode, motion artifact, various types of electrodes for biopotential measurement. [4]

Measurement of ECG, Einthoven triangle method, unipolar and bipolar limb leads, ECG amplifiers, Problems encountered in ECG recording [5]

Pacemakers, Different types of pacing modes, Physiological effects of electric currents. Defibrillators. [4]

Measurement of blood pressure, measurement of blood pH, measurement of blood flow, measurement of heart sounds, chemical tests on blood cells. [5]

X ray instrumentation. Ultrasonography, Magnetic Resonance Imaging, Application of telemetry in patient care. [4]

Text Books:

1. John Enderle. Joseph Brinzino, *Introduction to Biomedical Engineering*, Elsevier, 2012.
2. John G Webster, *Medical Instrumentation, Application & Design*, John Wiley & Sons, 2009.

Reference Books:

1. L. Cromwell, Fred J. Weibell, Erich A. Pfeiffer, , Biomedical Instrumentation & Measurements, PHI, 2014
2. A. C Guyton, John E Hall, Textbook of Medical Physiology, Elsevier, 2006.