M Tech in Bioelectronics

Semester I

Course Code	Course Name	Type	L	T	P	CR
BE509	Biomathematics	C	3	0	0	3
BE515	Basic Bioelectronics	C	3	0	0	3
BE511	Basic Bioelectronics Lab	C	0	0	4	4
BE519	Bioinspired Systems and Engineering	C	3	0	0	3
BE513	Biomedical Electronics	C	3	0	1	4
BE517	Biomedical Signal Processing	C	3	0	1	4
	Open Elective -I	OE				

Semester II

Course Code	Course Name	Type	L	T	P	CR
BE524	Advanced Bioelectronic Devices	C	3	0	1	4
BE518	Bioelectronic Systems and Controls	C	3	0	1	4
BE506	Biomedical Image Processing	C	3	0	1	4
BE504	Neuroengineering	C	3	0	0	3
EL540	Sensors and Sensor Intelligence	C	3	0	1	4
BE528	MEMS and Nanotechnology	E	3	0	0	3
	Open Elective -II	OE				

Semester III and IV

Course Code	Course Name	Type	L	T	P	CR
BE601	M. Tech. Dissertation	C				24

BE509: Biomathematics

Syllabus

Modeling of biophysical systems, differential equation formulation-linear and non-linear, solution techniques, finite element analysis, engineering design concept of some systems of human body, mathematical modeling of muscles, modeling the dynamic of human extremities, arm movement and its model, eye movement, cardiovascular modeling ,dynamics of heart, blood flow, respiratory modeling, mechanics of heart valves, mechanics of blood vessels.

Course Outcomes (COs)

At the end of this course students will demonstrate the ability to

1. Apply differential equation in engineering design of some systems of human body
2. Apply for mathematical modelling of human diseases
3. Apply cardiovascular respiratory modeling in different diseases of human body
4. Apply mathematical model in engineering solutions in different biological species
5. Discuss the standard protocols based on the biomathematical model in diagnosis of diseases

BE515: Basic Bioelectronics

Syllabus

Theory:

Basic Electronics: Semiconductor Materials, chemical and physical bonds, Intrinsic and extrinsic semiconductors, carrier motion in semiconductors – Drift, Diffusion And Recombination – Generation process, Boltzmann Transport equation, P-N junction diode, Bipolar Junction Transistor (BJT), Field Effect Transistor (FET), Operational Amplifier (OPAMP). Digital Logic: Boolean Algebra and logic gates, Combinational logic circuit, sequential logic circuit – flip flops. Biological materials: analogy between semiconductor and biological materials, water and electrolyte solutions; biological molecules - Proteins, Nucleic acids, Phospholipids; cell membrane; Eucaryotic cell. Motion in solution and chemical reaction: Diffusion, Brownian motion, electrophoresis, enzyme kinetics; Solid electrolyte junctions: electrode-electrolyte interfaces, Poisson –Boltzmann equation, Membrane transport, Nernst-Plank equation and solution.

Course Outcomes:

At the end of this course students will demonstrate the ability

1. For transformation of the conception acquired from the knowledge of properties exhibited by semiconductor materials to the Biological domain.
2. For transformation of conception acquired from the knowledge of characteristics shown by solid-solid junction to liquid-solid junction.
3. To acquire conceptual frame work for modeling bio-chemical activities compatible with semiconductor domain.
4. To exhibit the capability of knowledge required to hybridize electronics domain with bio-chemical domain.

BE519: Bioinspired Systems and Engineering

Syllabus

Biologically inspired artificial devices: artificial Heart and circulatory assist devices, artificial lungs, artificial kidney, artificial cell, artificial muscle.

Artificial vision: Computer vision – word recognition, feature extraction based on biological visual system, stereo vision; speech recognition.

Biologically inspired systems : Robotic systems and devices, acoustical systems, computing system such as neural network, bioinspired exploration, bioinspired computer architectures.

Course Outcomes (COs)

Upon completion of the course, the student will be able to

1. Understand the concept of biologically inspired artificial devices.
2. Understand the basic concept of biologically inspired computational methods.
3. Comprehend the concepts of feed forward neural networks and application of neural networks to real world systems.
4. Understand the basic concept of robotics and applications.

BE513: Biomedical Electronics

Syllabus

Physiological systems and Signals: Biology of the heart, circulatory and respiratory systems, auditory systems, physiology of nerve and muscle cells, fundamental organization of brain and spinal cord. Biosignals: Origin of bioelectric signals, electrocardiogram (ECG), phonocardiogram (PCG), encephalogram (EEG) and electromyogram (EMG).

(10 Lectures)

Physiological Transducers: Electrodes: silver-silver chloride electrodes, electrodes for ECG, EEG, EMG, Microelectrodes. Performance characteristics of transducers, classification of transducers based on Electrical principle involved: Resistive position transducer, resistive pressure transducer, inductive pressure transducer, capacitive pressure transducer; Self generating inductive transducer: linear variable differential transformer (LVDT), Piezoelectric Transducer.

(8 Lectures)

Recording Systems: Preamplifier, Signal conditioning: Differential amplifier, current to voltage converter, instrumentation amplifier; biomedical filters: LPF, HPF, bandpass, band stop (Notch filter); source of noise in low level measurement, Recording systems for ECG, PCG, EEG and EMG.

(6 Lectures)

Medical Imaging Systems: X-ray imaging, Computed tomography, ultrasonic imaging systems, Magnetic resonance imaging system, thermal imaging systems. Therapeutic equipments: Cardiac pacemaker, cardiac defibrillators, haemodylysis machine.

(6 Lectures)

Course Outcomes (COs)

Towards the end of the course the student will be able to –

1. Identify, formulate, and solve multi-disciplinary problems in the area of biomedical engineering by applying principles and technologies learned in BE-513.
2. Design a system, component, or process, and synthesise solutions to achieve desired needs for solving a problem in biomedical engineering.
3. Acquire and apply new knowledge as needed to work in the area of biomedical engineering.

BE517: Biomedical Signal Processing

Syllabus

Unit 1: Biomedical Signals:

- Genesis of bioelectric potential, ECG, EEG, and EMG
- Measurement of ECG, EEG and EMG
- Overview of analog signal analysis: time and frequency domain representation of signal
- Fourier series and Fourier transform
- Correlation, convolution and filtering
- Random signal-correlation and spectral representation

Unit 2: Digitization of Signal:

- Sampling theorem, quantization, quantizing effects
- A/D conversion, aliasing artifacts in biomedical signals

Unit 3: Discrete transforms:

- Discrete time Fourier transform, DFT and FFT
- Z-transform and properties

Unit 4: Digital filters:

- FIR and IIR filter
- Biomedical applications of digital filtering- removal of power line interference from ECG data, reducing ECG artifact from EMG data.
- ECG preprocessing, wave form recognition, morphological studies and rhythm analysis
- Automated diagnosis based on decision theory
- Optimal and adaptive filtering theory

Unit 5: Event Detection:

- Detection of events and waves in ECG
- Correlation analysis of EEG channels for EEG rhythm detection
- Matched filter for detection of EEG spikes

Course Outcomes (COs)

Towards the end of the course the student will be expected to –

1. Explain the basic principles of quantization and sampling for conversion of an analog signal to a digital signal.
2. Explain the concepts of discrete Fourier transform (DFT), z-transform, and Laplace transform.
3. Extend analog domain filter design to discrete-time using impulse invariance, bilinear transformations, etc.
4. Explain the formation of an electrical signal in any living system.
5. Identify different biomedical signals and explain how they are acquired from a human body.

6. Explain artifacts of biomedical signals and their removal using signal processing algorithms.
7. Explain detection of important physiological events from a biomedical signal.
8. Understand how bio-signals (after acquisition) are processed in one and higher dimensions.
9. Acquire basic skills needed to design a bioelectric signal analysis tool in MATLAB/Python and report their findings effectively.

BE524: Advanced Bioelectronic Devices

Syllabus:

Metal - Oxide - Semiconductor (MOS) : MOS Structure, Modes of operation, Metal Oxide Semiconductor Field effect Transistor (MOSFET). Electrolyte – Insulator – Semiconductor (EIS) : EIS Structure, Site binding Theory, Electrical double layer theory. MOSFET Based Bioelectronic devices : Biosensor overview, Ion Sensitive Field Effect Transistor (ISFET), Enzyme Field Effect Transistor (ENFET), Chemical Field Effect Transistor (CHEMFET), Reference Field Effect Transistor (REFET), Immune Field Effect Transistor (IMFET), Organic Thin Film Transistor (TFT), Cell-Based Biosensors & Sensors of Cell Metabolism, Light Addressable Potentiometric Sensors (LAPS); Interfacing of Biological Systems with electronic systems, non-conventional bioelectronic devices, conducting polymer based ISFET, Modeling & Simulation : SPICE and Electrochemical models of ISFET & CHEMFET.

Course Outcomes (COs):

At the end of this course students will demonstrate the ability

1. To use engineering concepts for transformation of basic solid phase building block to liquid-solid based structure like the transformation of MOS structure to EIS structure.
2. To acquire conceptual frame work for the design of Hybrid biological devices (bioelectronic devices).
3. To acquire conceptual frame work for electrochemical modeling of bioelectronic devices.
4. To know about the fabrication process along with hands on training involved in bioelectronics device fabrication.
5. To exhibit the capability of knowledge required to develop software for modeling and simulation of bioelectronic devices

BE518: Bioelectronic Systems and Controls

Syllabus

Bioelectronic systems, control theory applied to bioelectronic system modeling.
Linearization, transfer functions, Laplace transform, close loop system, design and simulationof controllers. Dynamic response and stability of control system. Bode design. Nonlinear control system, fuzzy control system ,adaptive control system and neural network based bioelectronic control systems. Some examples of control engineering in biologically inspired system, neuroengineering system, controlling electronic system using Event related potential (ERP).

Course Outcomes (COs)

Upon completion of the course, the student will be able to

1. Understand the basic concept of control system theory.

2. Understand the application of control system theory for analysing biological system.

3. Comprehend the neural networks to the application of neural networks to control systems.

4. Comprehend the fuzzy logic control to the application of fuzzy logic control to real world systems.

BE506: Biomedical Image Processing

Syllabus

Medical Imaging: X-ray imaging, computer assisted tomography magnetic resonance imaging, nuclear magnetic resonance imaging.
Image enhancement: Fundamental enhancement techniques, medical image enhancement with nonlinear filters.

Segmentation: Image segmentation basics, medical image segmentation by clustering, fuzzy clustering, segmentation by neural network, deformable modules and gradient vector flaw deformable modules, case studies of segmentation of brain, heart etc.

Image reconstruction from projections: Principle of tomography, algebraic and Fourier domain reconstruction technique .

Image registration: Physical basics of spatial distortion in medical images, fundamental of registration; application of image registration for image guided surgery.
Medical image compression: Fundamental and standards of image compression; issues related with medical image compression; medical image.

Course Outcomes (COs)

1. Understand the medical imaging technologies
2. Understand the concept of image transforms
3. Understand the medical image enhancement, restoration, segmentation techniques
4. Understand the medical image registration, compression techniques
5. Simulation of various medical image processing techniques in MATLAB

BE504: Neuroengineering

Syllabus

Biology of the neuron, biophysical description of the action potential, synapses, neuron as a threshold device, networks, neuroelectronic junctions, silicon neurons, SPICE modeling of Silicon neurons, Neural coding, models and methods, goal functions and time dependent learning rules, neural interfaces, EEG recording for brain computer interface applications, coding and decoding of neural information in bi-directional neural interfaces, Neuroengineering of mind : neural models of higher functions, large scale brain models, neural modeling and neural coding in the brain.

Course Outcomes (COs)

1. After completing the course BE 504, student is expected to have the basic knowledge of the Bio-neuro-engineering
2. After completion of this course, students will have knowledge to develope artificial circuit models that simulate the behavior of biological neuron is one of today's most promising directions of investigation in the field of neurobio and neuromorphic engineering.
3. Students will have knowledge to analyze the function of the nervous system, developing methods to restore damaged neurological function & creating artificial neuronal systems by integrating physical, chemical, mathematical & engineering tools.
4. Students are expected to work in the field of Bio-neuro engineering as project work or as per their interest

EL540: Sensors and Sensor Intelligence

Syllabus
Theory:

Unit 1: Classical sensors and transducers (10 hours):
Definition and classifications ; Working principle, materials and types of-Resistive sensors-potentiometer, strain gauge, RTD, thermistor; Capacitive- capacitive moisture, density and level measurement ; Inductive- RPM, flow measurement; Thermocouple; MEMS; Gas sensors ; Electrochemical sensors; ISFETs-glucose sensors; pulse, blood pressure and oxymeter

Unit 2: Intelligent Sensors (10 hours): Definition; Classifications- based on functions and techniques; Smart sensors- monolithic and hybrid; Soft sensors- modelling techniques, time sharing; Cogent sensors-monotype and multitype, classification, semantic transformation and decision making; Self adaptive sensors- adaptation to accuracy, time, power consumption and linearity;

Unit 3: Intelligent signal processing (10 hours): Metrological intelligence; Linearization techniques-circuit based linearization- OPAMP based, nonliner ADC; Look-up table; Piece-wise linearization; Interpolation; Error and drift compensation; Circuit based compensation-dummy circuit; Temperature compensation; Frequency based sensor- sensitivity control;

Unit 4: Artificial intelligence (10 hours): Human intelligence and machine learning; Biological and artificial neuron; Hardware realization of Neuron; Array based sensors; ANN based classification and discrimination, Recurrent ANN; E-tongue and E-Nose; Prognostic, diagnostic and predictive techniques in medical science, Fuzzy logic based techniques

Total: 40 lectures

Course Outcomes (COs)

Towards the end of the course the student will be expected to –

1. explain and differential classical and intelligent sensors
2. illustrate sensor and its intelligence
3. explain various Intelligent Sensor Standards and Protocols
4. illustrate artificial and adaptive intelligence
5. apply various intelligent signal processing techniques
6. develop basic artificial and adaptive neural networks for signal processing

BE528: MEMS and Nanotechnology

Syllabus

Introduction to MEMS: Micro and Nano-scale size domains; Evolution of MEMS Technology in Early Days, Moore's Law in MEMS, Prospects and Challenges in Commercialization of MEMS Technology Scaling laws in Miniaturization, MEMS materials and Processes; MEMS devices and Applications

(3 Lectures)

Introduction to Submicron Technology: Semiconductor materials; Photolithography; Doping; Thin film growth and Deposition; CVD and Ion Implantation, Metallization; Wet and Dry Etching; Silicon Micromachining; Metal MEMS Processes; Submicron Optical Lithography; Electron Beam Lithography; Soft Lithography and Printing.

(3 Lectures)

Mechanics of beam and diaphragm: Elasticity, Stress-Strain Relation, Bending Moment, Beam Bending Theory, Micro-cantilever Beam, Analysis of Deformation of Membranes.

(4 Lectures)

Sensing and actuation principles: Sensing Principles in MEMS: Piezoresistive, Capacitive, Thermoelectric, Thermoresistive etc. Actuation Principles in MEMS: Electrostatic, Thermal, Piezoelectric etc. Microactuators based on various principles: electrostatic, electromagnetic, piezoelectric, Capacitive and SMA; Pull in Effect, Actuator applications: Inkjet, Electrical and Optical Switching, Micropump.

(8 Lectures)

Case Studies: Physical sensor like pressure, chemical, flow sensor, accelerometer and gyroscope, inkjet nozzle, electrical and optical switching, micropumps etc.

(3 Lectures)

BioMEMS: Introduction, Chemical and Biomedical Sensing Mechanisms and Principles, Chem-Lab on a Chip, Chemoresistors, Chemocapacitors, Chemotransistors, DNA sensors.

(4 Lectures)

Microfluidics: transport in micro-channels; microfluidic components (filters, mixers, valves, and pumps)

(3 Lectures)

Nanotechnology: Nanomaterials: Quantum wire, quantum well, quantum dots, fullerenes, graphene, carbon nanotube; Synthesis of Nanomaterials: Physical methods (electrodeposition, sputtering, molecular beam epitaxy, spary pyrolysis), chemical methods (CVD, solvothermal etc) Top down and bottom up approach for nanofabrication: electron beam lithography, FIB lithography, soft lithography, nanoimprint, nanosphere, Dip-pen nanolithography, self assembly and chemical synthesis.

(4 Lectures)

Characterization Technique: scanning electron microscopy, scanning tunnelling microscopy, X-ray photoelectron spectroscopy, Surface enhanced Raman spectroscopy etc.

(2 Lectures)

Medical Application of Nanotechnology: Nano-biosensor, Nanotechnology in drug delivery

(2 Lectures)

Course Outcomes (COs):

1. Elucidate the principles of different types of MEMS sensors and actuators.
2. Explain the concept of MEMS design, and fabrication technology.
3. Acquire and apply new knowledge as needed to work in the area of microelectromechanical systems.
4. Apply the contemporary knowledge into the area of Biomedical Engineering.