**COURSE REQUIREMENTS FOR UNDERGRADUATE BIOMEDICAL ENGINEERING STUDENTS**

Termwise Course Curriculum for B.Sc Engg. (Biomedical) degree.

**Level-1, Term- I**

| Course No | Course Name | Type of course | Contact Hours | Credit Hours |
|---|---|---|---|---|
| Phy 123 | Waves and Oscillations, Optics and Thermal Physics | Theory | 3 | 3 |
| Chem 125 | Organic and Inorganic Chemistry | Theory | 3 | 3 |
| Math 113 | Calculus | Theory | 3 | 3 |
| BME 101 | Introduction to Biomedical Engineering | Theory | 3 | 3 |
| Hum187 | English | Theory | 3 | 3 |
| | | | 15 | 15 |
| Phy 102 | Physics Sessional - I | Sessional | 3 | 1.5 |
| Chem 126 | Organic and Inorganic Analysis Sessional | Sessional | 3 | 1.5 |
| Hum 104 | English Skills Sessional | Sessional | 3 | 1.5 |
| | | | 9 | 4.5 |
| Contact Hours 24.0; Credit Hours: 19.50 | | | | |

**Level-1, Term- II**

| Course No | Course Name | Type of course | Contact Hours | Credit Hours |
|---|---|---|---|---|
| Phy 167 | Electricity and Magnetism, Modern Physics and Mechanics | Theory | 3 | 3 |
| Chem 127 | Physical Chemistry | Theory | 3 | 3 |
| Math 115 | Complex Variable and Vector Calculus | Theory | 3 | 3 |
| EEE 171 | Electrical Circuits | Theory | 3 | 3 |
| BME 103 | Introduction to Living Cells and Human Anatomy | Theory | 3 | 3 |
| | | | 15 | 15 |
| Phy 152 | Physics Sessional - II | Sessional | 3 | 1.5 |
| Chem 128 | Physical Chemistry Sessional | Sessional | 3 | 1.5 |
| EEE 172 | Electrical Circuits Sessional | Sessional | 3 | 1.5 |
| | | | 9 | 4.5 |
| Contact Hours 24.0; Credit Hours: 19.50 | | | | |

**Level-2, Term- I**

| Course No | Course Name | Type of course | Contact Hours | Credit Hours |
|---|---|---|---|---|
| BME 201 | Biomechanics | Theory | 3 | 3 |
| EEE 273 | Basic Electronic Devices and Circuits | Theory | 3 | 3 |
| CSE 281 | Computer Programming | Theory | 3 | 3 |
| Math 213 | Differential Equations | Theory | 3 | 3 |
| Hum 245/ Hum 241 | Sociology/ Economics | Theory | 3 | 3 |
| | | | 15 | 15 |
| CSE 282 | Computer Programming Sessional | Sessional | 3 | 1.5 |
| BME 200 | Computer Aided Design in Biomedical Engineering Sessional | Sessional | 3 | 1.5 |
| EEE 274 | Basic Electronic Devices and Circuits Sessional | Sessional | 3 | 1.5 |
| | | | 9 | 4.5 |
| Contact Hours 24.0; Credit Hours: 19.50 | | | | |

**Level-2, Term- II**

| Course No | Course Name | Type of course | Contact Hours | Credit Hours |
|---|---|---|---|---|
| BME 203 | Human Physiology | Theory | 3 | 3 |
| BME 205 | Biofluid Mechanics and Heat Transfer | Theory | 3 | 3 |
| CSE 283 | Digital Techniques | Theory | 3 | 3 |
| Math 215 | Linear Algebra | Theory | 3 | 3 |
| MME 297 | Structure and Properties of Biomaterials | Theory | 3 | 3 |
| | | | 15 | 15 |
| BME 204 | Human Physiology Sessional | Sessional | 3 | 1.5 |
| BME 206 | Biofluid Mechanics and Heat Transfer Sessional | Sessional | 3 | 1.5 |
| CSE 284 | Digital Techniques Sessional | Sessional | 3 | 1.5 |
| MME 298 | Structure and Properties of Biomaterials Sessional | Sessional | 3 | 1.5 |
| | | | 12 | 6 |
| Contact Hours 27.0; Credit Hours: 21.00 | | | | |

**Level-3, Term- I**

| Course No | Course Name | Type of course | Contact Hours | Credit Hours |
|---|---|---|---|---|
| BME 301 | Bioelectricity | Theory | 3 | 3 |
| BME 303 | Biomedical Instrumentation and Measurements | Theory | 3 | 3 |
| CSE 391 | Embedded Systems and Interfacing | Theory | 3 | 3 |
| BME 311 | Biomedical Signals and Systems | Theory | 3 | 3 |
| Math 313 | Probability & Statistics | Theory | 3 | 3 |
| | | | 15 | 15 |
| BME 300 | Biomedical Engineering Design - I | Sessional | 3 | 1.5 |
| BME 304 | Biomedical Instrumentation and Measurements Sessional | Sessional | 3 | 1.5 |
| CSE 392 | Embedded Systems and Interfacing Sessional | Sessional | 3 | 1.5 |
| BME 310 | Communicating Protocols for Biomedical Instruments Sessional | Sessional | 3 | 1.5 |
| | | | 12 | 6 |
| Contact Hours 27.0; Credit Hours: 21.00 | | | | |

**Level-3, Term- II**

| Course No | Course Name | Type of course | Contact Hours | Credit Hours |
|---|---|---|---|---|
| ChE 477 | Biochemistry | Theory | 3 | 3 |
| BME 305 | Physiological Control Systems | Theory | 3 | 3 |
| BME 307 | Biomedical Transport Fundamentals | Theory | 3 | 3 |
| EEE 375 | Digital Signal Processing | Theory | 3 | 3 |
| EEE 377 | Random Signals and Processes | Theory | 3 | 3 |
| | | | 15 | 15 |
| BME 350 | Biomedical Engineering Design - II | Sessional | 3 | 1.5 |
| BME 306 | Physiological Control Systems Sessional | Sessional | 3 | 1.5 |
| EEE 376 | Digital Signal Processing Sessional | Sessional | 3 | 1.5 |
| | | | 12 | 4.5 |
| Contact Hours 27.0; Credit Hours: 19.50 | | | | |

**Level-4, Term- I**

| Course No | Course Name | Type of course | Contact Hours | Credit Hours |
|---|---|---|---|---|
| BME 401 | Molecular Biology for Engineers | Theory | 3 | 3 |
| BME 403 | Medical Imaging | Theory | 3 | 3 |
| Hum 415 | Professional Ethics | Theory | 3 | 3 |
| Elective - I | To be selected from the prescribed elective courses* | Theory | 3 | 3 |
| Elective - II | To be selected from the prescribed elective courses* | Theory | 3 | 3 |
| | | | 15 | 15 |
| BME 404 | Medical Imaging Sessional | Sessional | 3 | 1.5 |
| BME 400 | Project and Thesis | Sessional | 6 | 3 |
| | | | 9 | 4.5 |
| Contact Hours 24.0; Credit Hours: 19.50 | | | | |

**Level-4, Term- II**

| Course No | Course Name | Type of course | Contact Hours | Credit Hours |
|---|---|---|---|---|
| BME 405 | Healthcare System Management | Theory | 3 | 3 |
| BME 407 | Quantitative Physiology | Theory | 3 | 3 |
| Elective - III | To be selected from the prescribed elective courses* | Theory | 3 | 3 |
| Elective - IV | To be selected from the prescribed elective courses* | Theory | 3 | 3 |
| Elective - V | To be selected from the prescribed elective courses* | Theory | 3 | 3 |
| | | | 15 | 15 |
| BME 400 | Project and Thesis | Sessional | 6 | 3 |
| | | | 6 | 3 |
| | Contact Hours 21.0; Credit Hours: 18.00 | | | |

*** At least TWO elective courses must be taken from each of the two groups of elective courses**

| **Group – I**<br>**Biomechanics and Biomaterials** | **Group – II**<br>**Biosystems, Imaging and Instrumentation** |
|---|---|
| BME 409: Tissue Engineering<br>BME 411: BioMEMS<br>BME 413: BioMicro and Nanotechnology<br>BME 415: Bionanomaterials<br>BME 417: Advanced Biofluid Mechanics<br>BME 419: Implantable Systems<br>BME 421: Rehabilitation Engineering<br>BME 423: Human Assist Devices | CSE 493: Medical Informatics<br>CSE 495: Bioinformatics<br>BME 431: Telemedicine Systems<br>BME 433: Biosensors<br>BME 435: Introduction of Biophysics of Molecules and Cells<br>BME 437: Engineering Optics for Medical Application<br>BME 439: Neural Systems Modeling<br>BME 441: Neural Engineering<br>BME 443: Magnetic Resonance Imaging<br>BME 445: Biomedical Signal Processing |

| | |
|---|---|
| Hum: | 10.50 Credits |
| Math: | 15.00 Credits |
| Physics and Chemistry: | 18.00 Credits |
| BME: | 76.50 Credits # ( including life science of 6 credits) |
| Other Engineering: | 37.50 Credits # |
| Total: | 157.50 Credits |

# may vary depending on the elective subjects offered in the 4th Level

## DETAIL OUTLINE OF UNDERGRADUATE COURSES FOR UNDERGRADUATE STUDENTS OF BIOMEDICAL ENGINEERING

### Level 1 –Term I

**Phy 123: Waves and Oscillations, Optics and Thermal Physics**
3 credits, 3 hours/week

Waves and Oscillations: Differential equation of simple harmonic oscillator, Total energy, average energy and combination of simple harmonic oscillations, Spring mass system, Torsional pendulum; Two body oscillation, Reduced mass, Damped oscillation, Forced oscillation, Resonance; Progressive wave, Power and intensity of wave, Stationary wave, Group and phase velocities.

Optics: Defects of images: Spherical aberration, Astigmatism, Coma, Distortion, Curvature, Chromatic aberration. Theories of light; Interference of light: Young's double slit experiment, Displacement of fringes and its uses, Fresnel Bi-prism, Interference in thin films, Newton's rings, Interferometers; Diffraction of light: Fresnel and Fraunhoffer diffraction, Diffraction by single slit, Diffraction from a circular aperture, Resolving power of optical instruments, Diffraction at double slit and N-slits, Diffraction grating; Polarization: Production and analysis of polarized light, Brewster's Law, Malus Law, Polarization by double refraction, Nicol prism, Optical activity, Polarimeters.

Thermal Physics: Principle of temperature measurements: Platinum resistance thermometer, Thermo-electric thermometer, Pyrometer; Kinetic theory of gases, Maxwell's distribution of molecular speeds, Mean free path, Equipartition of energy, Brownian motion, van der Waal's equation of state, First Law of Thermodynamics and its application, Reversible and irreversible processes, Second Law of thermodynamics, Carnot cycle, Efficiency of heat engines, Carnot's theorem, Entropy and disorder, Thermodynamic functions, Maxwell relations, Clausius-Clapeyron equation, Gibbs phase rule, Third Law of Thermodynamics.

**Chem 125: Organic and Inorganic Chemistry**
3 credits, 3 hours/week

Structure of the atom: Particle and wave nature of light, light and other form of electromagnetic radiation, atomic spectra, Bohr model, quantum numbers, atomic orbitals; Periodic table: Periodic table, atomic radius, ionization energy, electron affinity, electronegativity.

Chemical bonding: Different types of bonding, details of covalent bonding, valence bond theory (VBT), molecular geometry, Valence Shell Electron Pair Repulsion (VSEPR) theory, hybridization of orbital, molecular orbital theory (MOT). Basic concepts of oxidation and reduction reaction.

Crystal structure, Ionic solid, Lattice, unit cell, Chemistry of hydrocarbons, Synthetic methods of common organic compounds, Reaction mechanism of typical organic reactions, Structure determination of organic compounds, Basic chemistry of biomolecules.

**Math 113: Calculus**
3 credits, 3 hours/week

Differential Calculus: Limits, continuity and differentiability. Successive differentiation of various types of functions. Leibnitz's theorem. Rolle's theorem, Mean value theorem, Taylor's and Maclaurin's theorems in finite and infinite forms. Expansion of functions. Evaluation of indeterminate forms by L'Hospital's rule. Partial differentiation, Euler's theorem. Tangent and Normal. Subtangent and subnormal in Cartesian and polar coordinates. Determination of maximum and minimum values of functions with applications. Curvature. Asymptotes.

Integral Calculus: Integration by the method of substitution. Standard integrals. Integration by successive reduction. Definite integrals, its properties and use in summing series. Walli's formulae. Improper integrals. Beta function and Gamma function. Area under plane curves and area of a region enclosed by two curves in Cartesian and polar coordinates. Volume and surface area of solids of revolution.

**BME 101: Introduction to Biomedical Engineering**
3 credits, 3 hours/week

Introduction to Biomedical Engineering and Careers in Biomedical Engineering; Human Biology: Chemical basis of life, Brief introduction to Human anatomy and physiology. Biomechanics: Introduction to Biomechanics: Force, Moments and Couples system; Musculo-Skeletal systems, Structures: Methods of Joints; Bio-materials and it interaction with tissue; Introduction to present-day medical measurements and relevant imaging and non imaging instruments; Biosensors: sensors for monitoring patients, Non-invasive biosensors for measuring metabolism and biophysical transport; The molecular biology and genetics starting with the chemistry and interactions of the key molecules of life: DNA, RNA, and protein; Computational biology: Algorithms for Biomedical/clinical data analysis for diagnostic, predictive, or prognostic purposes.

**Hum 187: English**
3 credits, 3 hours/week

General Discussion: Introduction; Various Approaches to Learning English; Grammatical Problems: Construction of Sentences; Grammatical Errors; Sentence Variety and Style; Conditionals; Vocabulary and Diction. Reading Skill: Discussing Readability; Scan and Skim Reading, Generating Ideas through Purposive Reading; Reading of Selected Stories. Writing Skill: Principles of Effective Writing; Organization, Planning and Development of Writing;

Composition; Précis Writing; Amplification. General Strategies for The Writing Process: Generating Ideas, Identifying Audiences and Purposes, Constructing Arguments, Stating Problems, Drafting and Finalizing; Approaches to Communication: Communication Today; Technical and non-Technical Communications; Different Types of Business Communication. Listening Skill: The Phonemic Systems and Correct English Pronunciation; Speaking Skill: Practicing Dialogue; Story Telling; Effective Oral Presentation; Report Writing: Defining a Report; Classification of Reports; Structure of a Report; Writing Report on Different Topics.

**Sessional courses**

**Phy 102: Physics Sessional - I**
1.5 credits, 3 hours/week

Based on Theory course Phy 123

**Chem 126: Organic and Inorganic Analysis Sessional**
1.5 credits, 3 hours/week

Experiments based on Chem 125

**Hum 104: English Skills Sessional**
1.5 credits, 3 hours/week

Grammar: Tense; Article; Preposition; Subject Verb Agreement; Clause; Conditional and Sentence Structure; Vocabulary Building: Correct and Precise Diction; Affixes; Level of Appropriateness; Colloquial and Standard; Informal and Formal; Developing Reading Skill: Strategies of Reading–Skimming, Scanning, Predicting, Inferencing; Analysis and Interpreting Variety of Texts; Practicing Comprehension From Literary and Non Literary Texts; Developing Writing Skill: Introduction to syntax; Clarity and Correctness of Sentences; Linking Sentences to Form Paragraphs; Writing Paragraphs, Essays, Reports; Formal and Informal Letters; Listening Skill and Note Taking: Listening to Recorded Texts and Class Lectures and Learning to Take Useful Notes Based on Listening; Developing Speaking Skill: Oral Skills Including Communicative Expressions For Personal Identification; Life at Home; Giving Advice and Opinion; Instructions and Directions; Requests, Complaints, Apologies; Describing People and Places; Narrating events.

## Level 1 –Term II

**Phy 167: Electricity and Magnetism, Modern Physics and Mechanics**
3 credits, 3 hours/week

Electricity and Magnetism: Coulomb's Law, Electric field, Electric flux, Gauss's Law and its application, Electric potential, Electric potential energy, Equipotential surfaces, Capacitors and capacitance, Dielectrics, Charging and discharging of a capacitor, RC and LC circuit, Current and Current density, Ohm's Law, Resistivity and Conductivity, Kirchoff's Law, Magnetic field, Magnetic induction, Magnetic force on a current carrying conductor, Torque on a current carrying loop, Hall effect, Faradays Law of electromagnetic induction, Lenz's Law, Self induction, Mutual induction.

Modern Physics: Galilean relativity and Einstein's special theory of relativity; Lorentz transformation equations, Length contraction, Time dilation and mass-energy relation, Photoelectric effect, Compton effect, de Broglie matter waves and its success in explaining Bohr's theory, Pauli's exclusion principle, X-ray production and application , Laser production and application, Constituent of nucleus, Nuclear binding energy, Different types of radioactivity, Radioactive decay Law, Radiation dose, Nuclear reaction: Nuclear fission, Nuclear fusion, Nuclear power plant.

Mechanics: Linear momentum of a system of particles, Conservation of linear momentum, Elastic and inelastic collisions, Angular Kinematics, Torque, Rigid Bodies, Moment of Inertia, Angular momentum of a system of particles, Conservation of angular momentum, Introduction to Fluid Mechanics, pressure, measuring pressure, Pascal’s & Einstein’s principle of fluid pressure, viscosity, laminar flow, turbulence, equation of continuity, Bernoulli’s equation, Introduction to Quantum Mechanics, Wave function, Uncertainity principle, Postulates of Quantum Mechanics, Schrödinger time independent equation, Expectation value, Probability, Particle in a zero potential, Calculation of energy.

**Chem 127: Physical Chemistry**
3 credits, 3 hours/week

General concepts: Stoichiometry, properties of gas, liquid and solid, gas laws; Solution: Types of solution, properties of solution, Raoults' law, colligative properties.

Electrochemistry: Conductance and electrical properties of solution, electrolytic cell, voltaic cell, commercial batteries, Fuel-cell.

Chemical Kinetics: Rate law, rate constant, order, molecularity, first order and second order reaction, Arrhenius equation, theories of reaction rate.
Thermochemistry and basic thermodynamics. Equilibria: Phase equilibria, chemical equilibria, acid-base equilibria, ionic equilibria.

**Math 115: Complex Variable and Vector Calculus**
3 credits, 3 hours/week

Complex Variable: Complex number system. General functions of a complex variable. Limits and continuity of functions of complex variables and related theorems. Complex differentiation and the Cauchy-Riemann equations. Infinite series & their convergence. Line integral of complex functions. Cauchy's integral formula. Liouville's theorem. Taylor's and Laurent's theorem. Singular points. Residue, Cauchy's residue theorem.

Vector Calculus: Differentiation and integration of vectors together with elementary applications. Line, surface and volume integrals. Gradient of a scalar function, divergence and curl of a vector function. Integral forms of gradient, divergence and curl. Gauss's divergence theorem, Stokes' theorem and Green's theorem for the plane.

**EEE 171: Electrical Circuits**
3 credits, 3 hours/week

Introduction to electric circuit: laws and theorems for DC circuit; AC circuit: circuit analysis techniques with phasors for single phase sinusoidal circuits (RL, RC and RLC), transient response of capacitor and inductor circuits, sinusoidal-steady-state response, resonance, four-wire system of generated emfs, balanced poly-phase circuits, three-phase three-wire system, power in balanced three-phase systems; Filter circuits: active and passive; Ideal operational amplifier circuits; Magnetic circuits; Transformer.

**BME 103: Introduction to Living Cells and Human Anatomy**
3 credits, 3 hours/week

Structure of the Cells; prokaryote vs. eukaryote, their function; Sub-cellular organells and their structures; Different cell types and their roles in physiology; Cell's response to their environment; Function of cell organelles and cell membrane.

Lower limb: Bones of lower limb; thigh; leg; Sole of foot Joints; Venous and lymphatic drainage; Arches of foot. Abdomen: Introduction to abdomen; Abdominal part : stomach; Small and large intestine; Large blood vessel of gut; Extrahepatic billiary apparatus; Spleen, Pancrease and liver; Kidney and ureter; Diaphragm; Posterior abdominal wall; Suprarenal gland and chromaffin system; Perineum; Urinary bladder and urethra; Boundary and contents of pelvis; Female and Male reproductive organ; Rectum and anal canal; Wall of pelvis. Upper limb: Bones of upper limb; Pectoral region; Axilla; Back; Cutaneous nerves, superficial veins and lymphatic drainage; Scapular region; Arm; Forearm and hand; Joints of upper limb.

Thorax: Bones and joints of thorax, wall of thorax, thoracic cavity and pleurae; Lungs;

Mediastinum; Pericardium and heart; Superior vena cava, aorta and pulmonary trunk; Trachea, oesophagus and thoracic duct.

Head and neck: Osteology head and neck; Scalp, temple and face; Side of neck; Back of neck; Contents of vertebral canal; Cranial cavity; Contents of orbit; Anterior triangle of neck; Parotid region; Temporal and infratemporal region; Submadibular region; Deep structure in neck; Prevertebral region; Mouth and pharynx; Nose and paranasal sinuses; Larynx; Ear; Eye ball.
Brain: Introduction; Meaning of the brain and spinal cord; Spinal cord; Cranial nerves; Brainstem; Cerebellum; ventricle and limbic system; Neural pathways and reticular formation;

**Sessional courses**

**Phy 152: Physics Sessional - II**
1.5 credits, 3 hours/week

Experiments based on Phy 167

**Chem 128: Physical Chemistry Sessional**
1.5 credits, 3 hours/week

Experiments based on Chem 127

**EEE 172: Electrical Circuits Sessional**
1.5 credits, 3 hours/week

Experiments based on EEE 171

## Level 2 –Term I

**BME 201: Biomechanics**
3 Credits, 3 hours / week

Principles of Equilibrium: Forces; moments and couples; equations of static equilibrium; structural idealization applications in biomechanics. Basics of stress and strain analysis.
Muscles and Movement: Skeletal muscle morphology; isotonic versus isometric construction; muscles constitutive modeling, whole muscle mechanics parallel versus pinnate muscle types; muscle and bone interactions.

Basic Statics and Movements at Specific Joints: Shoulder and Shoulder Girdle; Elbow and Forearm; Wrist and Hand; Trunk and Spine; Hip, Knee, Ankle; Patterns of movement. Structural and Functional Analysis; Adaptation of Major Tissues and Organs: Planes and axes of movement, Types of muscular contraction, Load and force of contraction; Basic Dynamics to Human Motion: Review of linear and angular kinematics; Kinetic equations of motion; Examples in biomechanics; Modern kinematic measurement techniques; Applications of human motion analysis; Introduction to Viscoelasticity.

**EEE 273: Basic Electronic Devices and Circuits**
3 credits, 3 hours/week

Introduction to semiconductors; p-type and n-type semiconductors; p-n junction diode characteristics; Diode applications: half and full wave rectifiers; clipping and clamping circuits; regulated power supply using zener diode. Bipolar Junction Transistor (BJT): principle of operation; I-V characteristics; Transistor circuit configurations (CE, CB, CC), BJT biasing; load lines; BJTs at low frequencies; Hybrid model, h parameters, simplified hybrid model; Small-signal analysis of single and multi-stage amplifiers; frequency response of BJT amplifier; Field Effect Transistors (FET): principle of operation of JFET and MOSFET; Depletion and enhancement type NMOS and PMOS; biasing of FETs; Low and high frequency models of FETs, Switching circuits using FETs; Introduction to CMOS. Operational Amplifiers (OPAMP): linear applications of OPAMPs, gain, input and output impedances; active filters; frequency response and noise.

**CSE 281: Computer Programming**
3 credits, 3 hours/week

Introduction to digital computers; Programming languages, algorithms and flow charts; Structured Programming using C: Variables and constants, operators, expressions, control statements, functions, arrays, pointers, structure unions, user defined data types, input-output and files; Object-oriented Programming using C++: introduction; classes and objects; polyorphism; function and operator overloading; inheritance.

**Math 213: Differential Equations**
3 credits, 3 hours/week

Ordinary Differential Equations: Formation of differential equations. Solution of first order differential equations by various methods. Solution of general linear equations of second and higher order with constant coefficients. Solution of homogeneous linear equations. Solution of differential equations of the higher order when dependent and independent variables are absent. Solution of differential equations by the method based on factorization of operators. Frobenius method.

Partial Differential Equations: Formation of partial differential equations. Solutions of linear and nonlinear partial differential equations of first order. Linear equations of higher order. Equations of the second order with variable coefficients. Wave equations. Particular solutions with boundary and initial conditions.

**Hum 245: Sociology**
3 credits, 3 hours/week

Introduction: Society; Science and Technology an Overview; Scientific Study of Society; Social Elements; Society, Community, Association and Institution; Mode of Production and Society; Industrial Revolution, Development of Capitalism. Culture and Socialization: Culture; Elements of Culture; Technology and Culture; Cultural Lag; Socialization and Personality; Family; Crime and Deviance; Social Control. Technology, Society and Development: Industrialization and Development; Development and Dependency Theory; Sustainable Development; Development and Foreign Borrowing; Technology Transfer and Globalization, Modernity and Environment; Problem and Prospects.

Pre-Industrial, Industrial and Post-Industrial Society: Common Features of Industrial Society; Development and Types of Social Inequality in Industrial Society; Poverty, Technology and Society; Social Stratification and Social Mobility; Rural Vs Urban Life; Evaluation of City Life; Population and Society: Society and Population; Fertility, Mortality and Migration; Science, Technology and Human Migration; Theories of Population Growth - Demographic Transition Theory; Malthusian Population Theory; Optimum population Theory; Population Policy..
.

**Hum 241: Economics**
3 credits, 3 hours/week

Introduction to Economics, Economics and Engineering, The Techniques of Resource: Allocation, Micro-Economics: Theory Of Utility And Preferences, Marginal Analysis. The; Theory of Demand and Supply and their Elasticities; Price Determination Indifference Curve countries; Indifference curve technique; Marginal analysis; Production; production function; Technique; Theory of Production and Cost; Theory of the Firm and Market Structure and market Optimization; Macro-Economics: Savings, Investment, Employment; National Income Analysis; Inflation: Demand Pull and Cost Push Inflation, Stagflation, Policies for Controlling Inflation. Economics of Development and Planning..

**Sessional courses**

**CSE 282: Computer Programming Sessional**
1.5 credits, 3 hours/week

This course consists of two parts. In the first part, students will perform experiments to verify practically the theories and concepts learned in CSE 281 In the second part, students will learn program design.

**BME 200: Computer Aided Design in Biomedical Engineering Sessional**
1.5 credits, 3 hours/week

Designing Biomedical systems using different commercial software packages.

**EEE 274: Basic Electronic Devices and Circuits Sessional**
1.5 credits, 3 hours/week

Experiments based on EEE 273.

**Level-2, Term- II**

**BME 203: Human Physiology**
3 credit, 3 hrs/week

Definition, goal & importance of physiology. Homeostasis: definition. major functional systems, control systems of the body. Cellular Physiology and Blood .Composition and function of blood. Cardiovascular Physiology: Properties of cardiac muscle, Generation of cardiac impulse and its conduction in the heart, Cardiac cycle, heart sound. Gastrointestinal Physiology: Physiological anatomy of gastrointestinal (GI) tract. Local hormones of GIT: name, functions & regulation of secretion. Renal physiology: Kidney, functions of kidneys. Respiration: Mechanism, Pulmonary & Alveolar ventilation Pulmonary volumes and capacities and dead space, Respiratory unit and respiratory membrane, Diffusion of Gases through the respiratory membrane, Transport of Oxygen & Carbon dioxide in blood. Hormones: Definition, Classification, mechanism of action, regulation of secretion. Functional organization and functions of major levels of central nervous system

**BME 205: Biofluid Mechanics and Heat Transfer**
3 credits, 3 hours/week

Concept of fluid continuum, forces acting on a fluid, Surface tension, Statics of fluids: equation of static equilibrium, manometers, forces on submerged surfaces; Fluids in motion: concept of

shear stress and classification of fluids; Fluid flow in closed conduits; laminar and turbulent flow; friction factor; control volume analysis: balance of mass, momentum and energy; continuity equation ; momentum equation; Bernoulli's principle; Newton's law of viscosity, Navier-Stokes equations, Exact solutions of Navier-stokes equations, Couette flow, Poiseuille flow, the Rayleigh problem.

Basic modes of heat transfer; Introduction to Heat Transfer in Biological System, Thermal regulation of human body; Theoretical determination of thermal properties for biomaterial and experimental techniques; Temperature measuring devices; Different approaches in bioheat transfer modeling.

**CSE 283: Digital Techniques**
3 credits, 3 hours/week

Digital Logic Design: Boolean algebra, logic gates and their truth tables, canonical forms, combinatorial logic circuits; Arithmetic and data handling logic circuits, decoders and encoders, multiplexers and demultiplextures; Flip-flops, Counters, Registers; Sequential logic circuits.

Digital Electronics: Diod logic gates, transistor gates, MOS gates; Logic Families: TTL, ECL, IIL and CMOS logic with operation details; Electronic circuits for flip-flops; A/D and D/A converters with applications; OP AMPs; Timing circuits.

**Math 215: Linear Algebra**
3 credits, 3 hours/week

Definition of matrices. Algebra of matrices. Transpose of a matrix and inverse of a matrix. Factorization. Determinants. Quadratic forms. Matrix polynomials. Eigenvalues and eigenvectors. Diagonalization.

Introduction to systems of linear equations. Gaussian elimination. Euclidean n-space. Linear transformations from $IR^n$ to $IR^m$. Properties of' linear transformations from $IR^n$ to $IR^m$. Real vector spaces and subspaces. Basis and Dimension. Row space, column space and null space. Rank and Nullity. Inner products. Angle and orthogonality in inner product spaces. Orthogonal basis: Gram-Schmidt process and QR-Decomposition. Linear transformations: Kernel and Range. Application to Computed Tomography.

**MME.297:.Structure and Properties of Biomaterials**
3 credits, 3 hours/week

Basic concepts of materials science. Classification, structure and properties of materials. Properties requirement of biomaterials and the concept of biocompatibility. Cell-material interactions and foreign body response, Genotoxicity assessment. Characterization of biomaterials. Processing and properties of important biometallic and bioceramic materials,

synthesis of biocompatible coating on structural implant materials. Processing and properties of polymer-based biocomposites.

**Sessional courses**

**BME 204 Human Physiology Sessional**
1.5 credits, 3 hours/week

Sessional based on BME 203.

**BME 206: Biofluid Mechanics and Heat Transfer Sessional**
1.5 credits, 3 hours/week

Experiments based on BME 205.

**CSE 284: Digital Techniques Sessional**
1.5 credits, 3 hours/week

Experiments based on CSE 283.

**MME.298: Structure and Properties of Biomaterials Sessional**
1.5 credits, 3 hours/week

Experiments based on MME 297.

## Level-3, Term- I

**BME 301: Bioelectricity**
3.00credits, 3 hours/week

Introduction to Bioelectricity and Excitable Cells. Bioelectric potentials and currents: ionic composition of excitable cells, Nernst-Planck equation, membrane structure, Nernst potential, parallel-conductance model; membrane channels: channel structure, biophysical methods for measuring channel properties, macroscopic channel kinetics, channel statistics, introduction to the Hodgkin-Huxley membrane model; Action potentials: observing action potentials, nonlinear membrane behavior, origin of action potential, resting and peak voltages, voltage and space clamp, Hodgkin-Huxley equations, simulation of membrane action potential, action potential characteristics, active transport, calcium channels and "other" membrane models; impulse propagation: core-conductor model, cable equations, local circuit currents during propagation, mathematics of propagating action potentials, propagation velocity constraint for uniform fiber, propagation in myelinated nerve fibers; electrical stimulation of excitable tissue: linear (subthreshold) response of a single spherical cells, linear (subthreshold) response of a cylindrical

fiber; extracellular fields: basic formulation, lumped fiber source models; cardiac electrophysiology, electrical nature of intercellular communication, source models, ECG measurement and analysis; the Neuromuscular junction: structure of the neuromuscular junction, evidence for the quantal nature of transmitter release, Poisson statistics for transmitter release, the effect of Ca2+ and Mg2+ on transmitter release, post-junctional response to transmitter; skeletal muscle: muscle structure, muscle contraction, structure of the myofibril, sliding filament theory, Excitation-contraction, EMG measurement and analysis; neural electrophysiology: structure of the nervous system, sensory transducers and neurons, neural synapses, excitation and inhibition, neural coding and computation, EEG measurement and analysis, brain-computer interfaces; Functional electrical stimulation: electrodes and electrode-tissue behavior, nerve excitation.

**BME 303: Biomedical Instrumentation and Measurements**
3 credits, 3 hours/week

Principles of a medical instrumentation system, properties of biomedical instrumentation and measurements: precision, resolution, accuracy, uncertainty, sensitivity, repeatability, calibration, maintenance and reparability, principles of biomedical transducers: , bio-physical parameters: force, displacement, temperature and velocity, resistive, capacitive, inductive, optical and ultrasonic transducers; laws of membrane biophysics: electrical properties of cells and electrical equivalent model for the cell membrane; action potential, Hogkin-Huxley model, principles of electroneurogram (ENG) and electromyogram (EMG), cardiovascular measurements: anatomy of the heart, principles of electrocardiography, measurement of blood pressure and blood flow, measurement of heart rate and heart rate variability, polyplethysmography (PPG) for heart rate measurement, brain signal measurements: brain anatomy, electrical potential from the brain, principles of electroencephalography, brain-computer interface; therapeutic and prosthetic devices: ventilator, inhaler, defibrillator, pacemaker, neural simulator, respirator, heart-lung machine etc., measurement of respiratory volumes and flow, bio-potential electrodes and amplifiers: polarisation, circuit models, interface between skin and electrodes, motion artifacts techniques for noise and interference reduction, grounding shielding, safety issues in medical equipment

**CSE 391: Embedded Systems and Interfacing**
3 credits, 3 hours/week

Introduction to embedded systems with applications: Overview of the design flow, Embedded system specification and modeling; Introduction to embedded processors and microcontrollers: types of processors, architecture, addressing modes, instruction sets, interrupts, parallelism; Memory architectures: memory technologies, memory hierarchy, memory models; memory interface; Bus interface; I/O hardware and interface; Integrating microcontrollers with interfacing chips; Programmable peripheral interfacing chip with interface to A/D and D/A converter; Programmable interrupt controller, DMA controller; Sensor and Actuators: models of sensors and actuators, common sensors, actuators; Interfacing to the external world through sensors and actuators.

**BME 311: Biomedical Signals and Systems**
3 credits, 3 hours/week

Biosignals and their non-deterministic properties, models of biomedical systems, basic operation on signals, elementary signals, representation of signals using impulse function. Properties of Linear Time Invariant (LTI) systems: Linearity, causality, time invariance, memory, stability, invertibility. Time domain analysis of LTI systems: Differential equations- system representation, order of the system, solution techniques, zero state and zero input response, system properties; impulse response- convolution integral, determination of system properties. Frequency domain analysis of LTI systems: Fourier series- properties, harmonic representation, system response, frequency response of LTI systems; Fourier transformation- properties, system transfer function, system response and distortion-less systems. Applications of time and frequency domain analyses: solution of analog electrical and mechanical systems, amplitude modulation and demodulation, time-division and frequency-division multiplexing. Laplace transformation: properties, inverse transform, solution of system equations, system transfer function, system stability and frequency response and application. Analog filter design methods for biomedical instrumentation

**Math 313: Probability and Statistics**
3 credits, 3 hours / week

Measures of central tendency and variation, Chebychev's theorem, z-scores, Frequency distribution, Graphical representation of data including stem, Leaf and Box Plot, Skewness, Kurtosis. Probability theory: Rules of probability, Conditional probability, Bayes's Theorem, Counting techniques. Random Variable: Concept of random variable, Discrete and Continuous random variable, variance of random variable and their properties. Discrete and Continuous Probability Distributions: Binomial, Multinomial, Negative binomial, Normal, Poisson, Exponential, Uniform, Gamma distribution. Sampling Theory: Sampling distribution of mean, and Sampling procedures. Regression and Correlation: ANOVA. Statistical Inference: Estimation of parameters. Hypothesis Testing: z-test, t-test and Goodness of fit.

**Sessional courses**

**BME 300: Biomedical Engineering Design - I**
1.5 credits, 3 hours/week

Integrated design of medical devices following related design considerations and cost estimation.

**BME 304: Biomedical Instrumentation and Measurements Sessional**
1.5 credits, 3 hours/week

Sessional based on BME 303.

**CSE 392: Embedded Systems and Interfacing Sessional**
1.5 credits, 3 hours/week

Sessional based on CSE 391.

**BME 310: Communicating Protocols for Biomedical Instruments Sessional**
1.5 credits, 3 hours/week

Sessional based on the protocols used in the state of the art Biomedical instruments.

**Level-3, Term- II**

**ChE 471: Biochemistry**
3.00credits, 3 hours/week

Introduction: molecular logic of living system. Biomolecules and cells. Sugars, polysaccharides, lipids-triglycerides, phospholipids, biological membranes. Proteins: amino acid sequences, primary, secondary, tertiary and quaternary structure; classification of proteins. Enzymes mechanism: kinetics and inhibition. Nucleic acid: nucleotides. DNA, RNA composition and simple structure; replication, transcription and translation. Genetic code and genetic engineering. Vitamins and coenzymes. Digestion of polysaccharides, lipids and proteins. Metabolism and energy transfer; glycolysis and oxidative phosphorylation; biological high-energy compounds. Oxidation of fatty acids and oxidative degradation of amino acids. Photosynthetic phosphorylation. Inter relationship and control metabolism. Some inborn errors of metabolism.

**BME 305: Physiological Control Systems**
3 credits, 3 hours / week

Introduction to physiological modeling: what is a model and why model, multi-scale organization of living organisms: cell to organ Homeostasis. Examples of physiological control systems.

Tools for modeling physical systems: Review of linear systems, Laplace transform, Fourier series and Fourier transform, system response in the time and frequency domains, transfer function, open loop control, feedback control, stability of systems, steady state and transient analysis, design of PID controllers.

Physiology of cardiovascular systems: Key events in the cardiac cycle, blood pressure and flow, vascular impedance, lumped parameter models, Windkessel model of circulation, cardiac mechanics.

Physiology of Endocrine system: Enzymes and hormones, Michaelis-Menten enzyme kinetics, examples of endocrine control: glucose insulin system, thyroid hormone system, Physiology of Nervous System: Anatomy and physiology of nerves, action potentials, Hodgkin-Huxley model, Physiology of Respiratory System: Respiratory mechanics, lung models.

Physiology of Musculoskeletal System: Muscle anatomy and physiology. How muscles contract Hill model of muscle contraction, Muscle stretch reflex.

Modeling complex physiological systems: Regulation of cardiac output: Starling's law, pressure volume curves, coupled model of cardiopulmonary system, Blood pressure regulation: Baroreceptor reflex, kidney for blood pressure regulation, Blood glucose regulation: insulin control of glucose, glucose utilization in muscle.

**BME 307: Biomedical Transport Fundamentals**
3 credits, 3 hours / week

Introduction to mass, momentum and heat transport in living systems; Basic hemodynamics; Use of the equations of continuity and motion to set up complex flow problems; Basic molecular mechanics of fluid and electrolyte transport across cell membranes and epithelia; Flow within distensible tubes; Shear stress and endothelial cell function; Mass transfer and metabolism in organs and tissues; Microscopic and macroscopic mass balances; Diffusion: mass transfer between fluids, membrane and pores; mass transfer coefficient; Blood-tissue transport of solutes in the microcirculation; Mass transfer in kidney dialysis; Compartmental models for pharmacokinetic analyses; Analysis of blood oxygenators; Unsteady state heat transfer modes and laws, heat transfer coefficient, heat transfer inside the body, heat transfer between body and surrounding; Analogy equations relating momentum, energy and mass transfer.

**EEE 375: Digital Signal Processing**
3 credits, 3 hours/week

Introduction to digital signal processing. Sampling and signal reconstruction. Analysis of discrete-time system in the time domain: impulse response model, difference equation model. Correlation of signals with biomedical applications. Z-transform and analysis of LTI systems. Frequency analysis of discrete-time signals: discrete Fourier series and discrete-time Fourier transform (DTFT). Frequency analysis of LTI systems. Discrete Fourier transform (DFT) and fast Fourier transform (FFT). Calculation of spectrum of biomedical signals. Digital filter design-linear phase filters, specifications, design using window, optimal methods; IIR filters-specifications, design using impulse invariant, bi-linear z-transformation, least-square methods.

**EEE 377: Random Signals and Processes**

3 credits, 3 hours/week

Probability and Random variables: Sample space, set theory, probability measure, conditional probability, total probability, Bayes theorem, independence and uncorrelatedness. Expectation, Variance, moments and characteristic functions. Commonly used distribution and density functions. Central limit theorem. Transformation of a random variables: one, two and N random variables. Joint distribution, density, moments and characteristic functions, system reliability.

Random Processes: Correlation and covariance functions. Process measurements. Gaussian, and Poisson random processes. Markov Process**.** Noise models. Stationarity and Ergodicity. Spectral Estimation. Correlation and power spectrum. Cross spectral densities. Response of linear systems to random inputs, Optimal filters: Wiener and matched filters, Statistical Estimation Techniques (ML, MMSE, MAP).

**Sessional Courses**

**BME 350: Biomedical Engineering Design - II**
1.5 credits, 3 hours/week

Construct/ develop the medical device designed in BME 300: Biomedical Engineering Design I course and test its performance.

**BME 306: Physiological Control Systems Sessional**
1.5 credits, 3 hours/week

Sessional based on BME 305.

**EEE 376: Digital Signal Processing Sessional**
1.5 credits, 3 hours/week

Sessional based on EEE 376.

**Level-4, Term- I**

**BME 401: Molecular Biology for Engineers**
3 credits, 3 hours/week

Introduces the fundamentals of cell structure and function: chemistry, organelles, enzymes, membranes, membrane transport, intracellular compartments and adhesion structures; energy flow in cells concentrates on the pathways of glycolysis and aerobic respiration; information

flow in cells focuses on modern molecular biology and genetic engineering, and DNA replication, the cell cycle, gene expression, gene regulation, and protein synthesis. Cytoskeleton and signal transduction. Cancer, Cell junctions, cell adhesion and the extracellular matrix. Development of multicellular organisms. Specialized tissues and stem cells Innate immunity and adaptive immune system.

**BME 403: Medical Imaging**
3 credits, 3 hours / week

Introduction to imaging, medical imaging modalities, Medical imaging before x-rays, Hippocratic thermography, dissection, laproscopy, X-radiography, Computed tomography (CT), evolution of CT scanner design, image reconstruction algorithms, filtered back-projection method, iterative method, low dose computed tomography, Ultrasound, Sonar and other early applications of acoustics, basic principles of ultrasound imaging, Evolution of ultrasound technology and clinical applications, Magnetic resonance imaging, Early use of nuclear magnetic resonance (NMR) spectroscopy, Principles of NMR and MRI, Evolution of magnetic resonance imaging (MRI) technology and clinical applications, development and applications of functional MRI, Nuclear imaging.

**Hum 415: Professional Ethics**
3 credits, 3 hours/week

Definition and scope of Ethics, Different branches of Ethics, Social Change and the Emergence of New Technologies; Public Health and Public safety; Human qualities of an Engineer, Applied Ethics in Engineering: Ethical Issues in Design and Manufacturing; Risk analysis; Cost-benefit analysis; Resources Allocation; Ethical Expectations: Professional Restrictions and Professional Responsibility; Responsibilities of Biomedical Engineer; Obligation of an Engineer to the Clients, Rights of Engineers; History and Development of Engineering Ethics; Institutionalization of Ethical Conduct: The Ethics of Engineering Organizations, Professional Codes of Ethics, Negligence; Inter Professional Relationship; Conflicts of Interests.

Medical ethics, Ethical Conflicts, Bioethical Principles, The Patient-Physician Relationship, Autonomy and Privacy of Patients; Professional Conduct and confidentiality, Truth Telling, the Hippocratic Oath; Biotechnologies: Reproductive Techniques, Genetic Engineering, Clinical Trials, Abortion, Genetic Testing Issues, Humane Experiment, Euthanasia; Protection of Human and Animal Subjects

**Sessional courses**

**BME 404: Medical Imaging Sessional**
1.5 credits, 3 hours/week

Experiments based on BME 403.

## Level-4, Term- II

**BME 405: Healthcare System Management**
3credit, 3 hours/week

Introduction on Leadership in Healthcare, Dealing with Hybrid roles in Healthcare Management, The influence of Professional Habitus on Healthcare Leadership, Healthcare organizations. Introduction to the codes, standards, ethical issues and regulations governing Healthcare Technology practices; Implications of Safe Medical Device Act (SMDA); Impact of regulatory agencies' (SFDA, JC, etc) requirements on the operations of the Healthcare Technology Management (HTM) program; Development of related policies and procedures govern activities such as the selection, planning, and acquisition of medical devices for their safe use; Patient Safety and Privacy; Safety programs; Infection control; Types of Contracts and Contract negotiation; Development and operation of a Healthcare Technology Management/Clinical Engineering Department in a Hospital.

**BME 407: Quantitative Physiology**
3 credits, 3 hours/week

Introduction to Physiology, Introduction to Simulation, Review of the nervous system, Action potential modeling, Pathophysiology of the nervous system, Peripheral Nervous System, Skeletal Muscles Dynamic Response, Stability, Synaptic Transmission, Neuromuscular Junction, Muscle Afferents, Somatosensory System, Pathophysiology of the cardiovascular system, Electrical activity modeling, Models of circulation, Cardiac regulation, Review of the respiratory system, Respiratory modeling, Respiratory regulation, Pathophysiology of the respiratory system. Students will work on quantitative problems.

## ELECTIVE COURSES

**BME 409: Tissue Engineering.**
3credit, 3 hours/week

Introduction and basic principles of cell biology, biomaterial scaffolds, Tissue culture basics, primary cells vs. cell lines, sterile techniques, guided tissue regeneration, soluble regulators -

growth factors or their genes – gene therapy, and bioreactors for the regeneration of tissues and organs in vitro and in vivo Oxygen transport, diffusion, Michalies-Menten kinetics, oxygen uptake rates, limits of diffusion Principals of self assembly. cell migration,3D organization and angiogenesis, principals of Skin tissue engineering, scarvs, regeneration, split skin graft, apligraf, Cardiovascular tissue engineering, blood vessels structure, vascular grafts, Liver tissue engineering, bio artificial liver (BAL) assist device, shear forces , plasma effects, self-assembled organoids, decelluarized whole livers, basic principles of stem cells, Different stem cell types and their potential for clinical applications

**BME 411: BioMEMS**
3credit, 3 hours/week

Introduction to bioMEMs: sensors actuator mechanisms for biomems, biocompatibility, reliability and regulatory considerations, slicon microfabrication, soft fabrication and polymers, micropatterning of substrates and cells; microfluidics: transport process, electrokinetic phenomena, microvalves, micromixers and micropumps; micro-total-analysis systems (μTAS): lab on a chip, capillary electrophoresis array, cell, molecule & particle handling, microspheres and cell based bioassays; MEMS for in vivo sensing and electrical impedence spectroscopy for non-invasive measurement of cells, MEMs ultrasonic transducers; bioMEMS for drug delivery applications; bioMEMs for tissue engineering: cell culture microdevices for tissue engineering, microscaffolding, micropatterned cocultures & morphogenesis; genomics & DNA microarrays: introduction to genomics, polymerase chain reaction, gene expression profiling, DNA microarrays, pharmacogenomics; proteomics & protein microarrays: mass spectroscopy, protein lab on a chip devices and bioinformatics; emerging applications of bioMEMs: implantable neuroprobes, ocular implants, cellular microinjections for therapeutic applications, minimally invasive surgery, endoscopy, ophthalmology, cardiovascular and dermabrasionapplications etc; hybrid MEMs: integrating inorganic structures into live organisms; packaging, power, data, safety and biocompatibility.

**BME 413: BioMicro and Nanotechnology**
3credit, 3 hours/week

Introduction: nano-dimension and paradigm shift, definitions, background, current practice and its multidisciplinary concepts, advances in technology from microelectronics to single electronics; Nanofabrication & characterisation: Nanoscale lithography, scanning probe microscopy;atomic force microscopy, scanning electron microscopy, transmission electron microscopy, LPCVD, epitaxy, cleaning, etch processes, metal deposition &nano-chip fabrication, Structural principal of bionanotechnology: Self assembly&self organisation, intermolecular interaction &moleculer recognition, self-assembled monolayers, protein folding, self assembled bottom up approaches of nanomaterial growth and top down paradigm; Nanomaterials& nanostructures: Nanoscale carbon, carbon nanotubes, fullerenes, quantum dots and nanocomposites; Moleculer electronics: Probing moleculer devices, transport mechanisms and integration strategies; Nano drug delivery: techniques, chemistry, advantages & challenges; Biomoleculer design: molecules, proteins, DNA and cells, DNA for coding and information storage, behaviour of molecules in solution, recombinant DNA technology, monochlonal antibodies and molecular modelling; Functional principal of bionanotechnology: information

driven nano assembly, energetics, chemical transformation, regulation, biomoleculer sensing and self replication; Biomimetic nanostructures; biomoleculer motors; current trends and future perspectives.

**BME 415: Bionanomaterals**
3credit, 3 hours/week

Introduction: Biomedical applications of post CMOS devices, required material properties and its multidisciplinary concepts; Nan materials based on conventional nanoelctronics: Single-crystalline, poly-crystalline and amorphous silicon/germanium thin film and nanowire synthesis methods and their biomedical applications, Carbon based nanomaterials: graphene, fullerene and nanotubes; III-V nanomaterials; Metal oxide thin film and nanowires; gold, silver and other metal oxide nanoparticle synthesis methods and applications; polypyrol and molybdenum-di-sulfide material system; Cellulose synthesis process, characterization and properties; biocomposites processing, characterisation and properties; self and direct assembling of bionanomaterials; ceramic smart drug delivery nanomaterials; polymersomes & their biological implications; amorphous coordination polymer particles for biomedicines; magnetic nano-particles for drug delivery; nanomaterial based bioimaging probes; gold nanostructures for therapy; moleculer bases of nanotoxicology; bioinspired nanomaterials synthesis process and applications; bionanomaterials for dental applications: nanostructured stainless steel, shape memory TiNi materials and applications of bulk nanostructured materials in dentistry. Future prospects, limitations, new materials for biomedical applications.

**BME 417: Advanced Biofluid Mechanics**
3 credits, 3 hours/week

Review of basic fluid mechanics. Biorheology: Constitutive equations. Non-Newtonian fluid models. Circulatory biofluid mechanics: Circulatory system physiology; Function of circulatory system, circulation in heart, blood and lymphatic vessels, Blood properties. Hemorheology. Models for blood flow: Steady flow in tubes, Pulsatile flow in a rigid tube, Pulsatile flow in an elastic tube. Wave propagation in elastic tubes. Applications in circulatory system: Blood flow dynamics in arteries and veins. Flow in specific vessels and arteries. Heart-valve hemodynamics. Diseases related to obstruction of blood flow. Stroke. Heart injury. Synovial fluid in joints: Synovial joints physiology, Function of synovial fluid, Diseases, Synovial fluid properties and rheology, Lubrication theory. Application for synovial fluid flow. Arthritis. Knee and Hip injury. Biofluid dynamics of the human brain: Cerebrospinal fluid, Cerebral blood flow, Blood brain barrier, Brain diseases. Respiratory biofluid mechanics: Respiratory system physiology Alveolar ventilation, Air flow in the lungs, Mechanics of breathing, Gas exchange and transport. Flow and pressure measurement techniques in human body.

**BME 419: Implantable Systems**
3 credits, 3 hours/week

Structure of the tissue-implant interface; surface characterization of biomaterials; protein adsorption; mechanisms of cell responses; the methods for controlling the tissue-implant interface, with emphasis on orthopedic and cardiovascular applications. Development of

algorithms efficient for hardware implementation. Short range wireless communication and inductive powering for medical devices Short distance wireless communication. Galvanic insulation. Inductive powering and communication. Wireless body area networks. The design process and the requirements for documentation of the design and the design process for biomedical devices. Regulations and standards for biomedical devices. Safety aspects in the design of biomedical devices, in particular the electrical safety aspects

**BME 421: Rehabilitation Engineering**

Introduction to rehabilitation engineering; Design and Prescription of prosthetic limbs, orthotic seating and positioning systems; Introduction to injuries, disability, human movement, kinesiology, Gait analysis: prosthetics and mobility assist technology; Improvement of performance and prevention of injuries.

**BME 423: Human Assist Devices**

Cardiac assist devices: Principle of External counter pulsation techniques, intra aortic balloon pump, Auxiliary ventricle and schematic for temporary bypass of left ventricle, prosthetic heart valves. Hemodialyzers: Artificial kidney, Dialysis action, hemodialyzer unit, membrane dialysis, portable dialyzer monitoring and functional parameters. Hearing aids: Common tests of audiograms, air conduction, bone conduction, masking techniques, Hearing aids principles, drawbacks in the conventional unit, DSP based hearing aids. Orthoesthetic and orthopedic devices: Hand and arm replacement , different types of models, externally powered limb prosthesis, feedback in orthopedic system, functional electrical stimulation, Sensory assist devices. Stimulator and respiratory assist devices: Stimulation, Practical applications of Stimulation, bio-feedback, Ventilator, Nebulizer, Humidifier.

**CSE 493: Medical Informatics**
3 credits, 3 hours / week

Integration of Information technology and Biomedical Engineering. Introduction to networking, communications, and information infrastructures in medical environment. Exposure to basic concepts related to networking at several levels: low-level (TCP/IP, services), medium-level (network topologies), and high-level (distributed computing, Web-based services) implementations. Commonly used medical communication protocols (HL7, DICOM) and current medical information systems (HIS, RIS, PACS). Advances in networking, such as wireless health systems, peer-to-peer topologies, grid/cloud computing. Introduction to security and encryption in networked environments.

**CSE 495: Bioinformatics**
3credit, 3 hours/week

Introduction to algorithms and computational complexity; Basic graph theoretic terminologies; Graph algorithms: DNA sequencing, DNA fragment assembly, Spectrum graphs; Sequence

similarity; Suffix Tree and variants with applications; Genome Alignment: maximum unique match, LCS, mutation sensitive alignments; Database search: Smith-Waterman algorithm, Fast A, BLAST and its variations, Locality sensitive hashing; Multiple sequence alignment; Phylogeny reconstruction; Phylogeny comparison: similarity and dissimilarity measurements, consensus tree problem; Genome rearrangement: types of genome rearrangements, sorting by reversal and other operations; Motif finding; RNA secondary structure prediction; Peptide sequencing; Population genetics.

**BME 431: Telemedicine System**
3credit, 3 hours/week

Introduction & Benefits of telemedicine. Communication infrastructure-LAN and WAN technology. Satellite, Mobile, Internet technology for telemedicine. Video and audio conferencing. Medical information storage and management for telemedicine, patient information, medical history, test reports, medical images, diagnosis and treatment. Hospital information systems, Doctors, paramedics, facilities. Pharmaceutical, Security and Confidentially of medical records and access control. Cyber laws, Access to health Care Services, Health Education and Self Care. Bio-modeling, medical data coding and compression, Functions of DICOM, PACS and HIS for Telemedicine.

**BME 433: Biosensors**
3credit, 3 hours/week

Overview of biosensors and transducer fundamentals; biosensor modeling & theory: variable rate coefficient, fractal analysis, The Mautner Model, analyte capture kinetics, binding and dissociation; Micro & nanotechnological sensing (e.g. electrical and electrochemical methods, absorption/transmission visible light spectroscopy); bimolecular detection and bimolecular recognition themes (e.g. DNA-DNA and protein-antibody interactions); Surface chemistry of nanofabricated structure; Surface immobilization of biomolecules, passivation of biofunctionalized surfaces, assessment of retention of bimolecular activity; Fabrication of biosensors, Medical application of biosensors: diagnostics, drug discovery; Detection of gases on biosensor surface; Toxin & pollutant detection; Biosensor platforms: Enzyme-based biosensors, Antibody-based biosensors, DNA-based biosensors, Optical biosensors, Mechanical biosensor, Electrochemical biosensors; Evolution from conventional diagnostic platform ELISA towards fast quadrant, Luminex, surface Plasmon resonance, micro cantilevers, quartz crystal microbalance and nanowire based nansensors; Nanosensor platforms: carbon nanotube sensors, silicon nanowire biosensors, metal oxide and III-V nanowire biosensors; Biofouling and multiplexing; Data analysis and performance factors; Future prospects, limitations, new materials and methods for biosensing.

**BME 435: Introduction of Biophysics of Molecules and Cells**
3credit, 3 hours/week

Introduction to the physical principles that underlie phenomena in cell biology and the properties of biomolecules. Basic review of cell and molecular biology, biorheology, Brownian motion,

molecular interactions in macromolecules, protein and nucleic acid structure, physics of biopolymers, chemical kinetics, mechanical and adhesive properties of biomolecules, molecular manipulation techniques, cell membrane structure, membrane channels and pumps, molecular motors, cell receptor/ligand interaction, cell adhesion and movement

**BME 437: Engineering Optics for Medical Application**
3credit, 3 hours/week

Introductory overview of optical phenomena and the optical properties of biological tissue. Fundamentals of optical systems design, integration and analysis used in biomedical optics. Design components: light sources, lenses, mirrors, dispersion elements optical fiber, detectors. Systems integration: radiometry and interferometer. Optical system analysis: resolution, modulation transfer function, deconvolution, tissue optics and noise. Optical imaging applications in biology and medicine: reflection, refraction, interference, diffraction, polarization, light scattering and fluorescence, and their application in biomedical imaging and microscopy.

**BME 439: Neural Systems Modeling**
3 credits, 3 hours/week

Classical Neural Modeling Techniques and Applications
Hodgkin-Huxley model of the excitable membrane: origin of the resting potential, electrical circuit model, phase plane, compartmental models, cable theory; linear systems: muscle model, vestibulo-ocular model, muscle spindle model, photoreceptor model, control and stability, pupillary control model; data acquisition and frequency domain analysis: autoregressive models; pattern recognition applied to action potential sorting: principal components, neural networks, neurobiological example.

fMRI for Investigating Neuro-Cognitive Function
Introduction to functional magnetic resonance imaging (fMRI): measurement vs manipulation techniques, contrast and resolution, principles and physical basis of BOLD fMRI, BOLD fMRI Properties, design and analysis of fMRI experiments, from neuronal to hemodynamic activity; preprocessing of fMRI signals: signal and noise, effects of field strength on fMRI data, sources of noises, slice time correction, head motion prevention and correction, distortion correction, functional and structural coregistration, temporal and spatial filtering; Advanced fMRI, combing fMRI with other techniques, direct cortical stimulation, single unit recording, electrical field potentials, neuronal generators of field potentials, combining fMRI with EEG and fNIRS, real-time fMRI.

**BME 441: Neural Engineering**
3 credits, 3 hours/week

Introduction to neural engineering and design; basic principles of brain anatomy; visual processing; Retinal implants; introduction to electroencephalogram (EEG); visual evoked potentials in EEG; auditory processing; cochlear implants; neural signal processing; motor

cortex; somatosensory cortex; sensorimotor brain-computer interfaces (BCIs); electrical stimulation modalities.

Basal ganglia; deep brain stimulation; brain plasticity and neurorehabilitation; real-time functional magnetic resonance imaging (fMRI) BCIs; real-time functional magnetoencepholgram (MEG) BCIs; BCI application I: psychiatric disorders; BCI application II: neurological disorders; BCI application III: movement disorders; structural connectivity in the brain; prediction of neurological disease; functional near infrared spectroscopy (fNIRS) BCIs; optogenetics.

**BME 443: Magnetic Resonance Imaging**
3credit, 3 hours/week

Basic concepts of MRI, Spin physics: Nuclear Spin, interactions with applied magnetic fields, rf-excitation, FID, T1, T2, T2* Relaxation, Bloch equations, Imaging principles: magnetic field gradients, spatial localization, frequency encoding, imaging equation, Fourier transform, slice selection, phase encoding, echoes, k-space, rf-excitation revisited, finite sampling, pulse sequence design, Fundamental MRI techniques: Spin echo, Gradient echo, Imaging considerations: Image contrast, steady state, diffusion imaging, SNR, Image Quality, Artifacts, Chemical Shift, Spectroscopy, 3D imaging, Field inhomogeneity, Susceptibility, T2*, Contrast agents, MR-signal phase, phase-contrast MRI, elastography, Advanced imaging principles: Fast imaging, parallel imaging, functional MRI, Advanced applications: cardiovascular MRI, MR Angiography.

**BME 445: Biomedical Signal Processing**
3 credits, 3 hours/week

Review of human anatomy and cell physiology; different types of biomedical signals: electroencephalogram (EEG), electrocardiogram (ECG), electrocorticogram (ECoG), electromyogram (EMG), electrooculogram (EOG), magnetoencephalogram (MEEG), respiratory sounds, hear sounds etc.; biomedical signal recording system: spectral characteristics of biomedical signals, bio-sensors and acquisition of biomedical signals, sampling, quantization and encoding, multi-rate systems, compressed sensing; time-domain analysis of biomedical signals; statistical analysis of biomedical signals using HOS, PCA, ICA, SVD, SSA etc. Estimation of power spectrum and correlation analysis; time-frequency domain analysis of biomedical signals: short-time Fourier transform, discrete-cosine transform (DCT), wavelet transform, empirical mode decomposition; digital filters for processing biomedical signals: different types of artifacts and noise, filters in time-domain and frequency-domain, time-frequency domain-based filtering; event detection and feature extraction: signal segmentation, envelope extraction, temporal and spectral features, statistical features, pattern classification using neural networks and support vector machine; modeling biomedical systems: autoregressive model, pole-zero and spectral modeling, applications of biomedical systems.