COURSE REQUIREMENTS FOR UNDERGRADUATE BIOMEDICAL ENGINEERING STUDENTS

Termwise Course Curriculum for B.Sc Engg. (Biomedical) degree.-2022

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 145	Chemistry - I	Theory	3	3
Math 113	Calculus	Theory	3	3
BME 101	Introduction to Biomedical Engineering	Theory	3	3
Hum 187	English	Theory	3	3
			15	15
Phy 102	Physics Sessional - I	Sessional	3	1.5
Chem 146	Inorganic and Physical Chemistry Sessional	Sessional	3	1.5
Hum 104	Developing English Skills	Sessional	3	1.5
			9	4.5
Contact Hours: 24.0; Credit Hours: 19.5				

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 147	Organic 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 148	Organic Chemistry Sessional	Sessional	3	1.5
EEE 172	Electrical Circuits Sessional	Sessional	3	1.5
BME 150	Computer Aided Design in Biomedical Engineering Sessional	Sessional	3	1.5
			12	6
Contact Hours: 27.0; Credit Hours: 21.0				

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
Math 213	Differential Equations	Theory	3	3
CSE 281	Computer Programming	Theory	3	3
BME 203	Human Physiology	Theory	3	3
			15	15
CSE 282	Computer Programming Sessional	Sessional	3	1.5
BME 204	Human Physiology Sessional	Sessional	3	1.5
EEE 274	Basic Electronic Devices and Circuits Sessional	Sessional	3	1.5
BME 202	Biomechanics Sessional	Sessional	1.5	0.75
			10.5	5.25
Contact Hours: 25.5; Credit Hours: 20.25				

Level-2, Term- II

Course No	Course Name	Type of course	Contact Hours	Credit Hours
BME 211	Bioelectricity	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
BME 207	Biomaterials	Theory	3	3
			15	15
BME 210	Numerical Techniques Sessional	Sessional	1.5	0.75
BME 206	Biofluid Mechanics and Heat Transfer Sessional	Sessional	3	1.5
CSE 284	Digital Techniques Sessional	Sessional	3	1.5
BME 208	Biomaterials Sessional	Sessional	3	1.5
			10.5	5.25
Contact Hours: 25.5; Credit Hours: 20.25				

Level-3, Term- I

Course No	Course Name	Type of course	Contact Hours	Credit Hours
BME 309	Quantitative Physiology	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 and 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
			10.5	5.25
Contact Hours: 27.0; Credit Hours: 21.0				

Level-3, Term- II

Course No	Course Name	Type of course	Contact Hours	Credit Hours
BME 317	Biochemistry for Biomedical Engineers	Theory	3	3
BME 305	Biomedical Control Systems	Theory	3	3
BME 307	Biomedical Transport Fundamentals	Theory	3	3
EEE 375	Digital Signal Processing	Theory	3	3
BME 313	Molecular Biology and Immunology	Theory	3	3
			15	15
BME 350	Biomedical Engineering Design - II	Sessional	3	1.5
BME 306	Biomedical Control Systems Sessional	Sessional	3	1.5
EEE 376	Digital Signal Processing Sessional	Sessional	3	1.5
BME 320	Industrial Attachment	Sessional	3 weeks	1
			9	5.50
Contact Hours: 24.0; Credit Hours: 20.5				

Level-4, Term- I

Course No	Course Name	Type of course	Contact Hours	Credit Hours
Hum 445/ Hum 441	Sociology/Engineering Economics	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	4.50
Contact Hours: 24.0; Credit Hours: 19.5				

Level-4, Term- II

Course No	Course Name	Type of course	Contact Hours	Credit Hours
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
BME 405	Healthcare System Management	Theory	3	3
BME 447	Clinical Engineering	Theory	3	3
			15	15
BME 400	Project and Thesis	Sessional	6	3
			6	3
Contact Hours: 21.0; Credit Hours: 18.0				

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

Group – I Biomechanics & Biomaterials	Group – II Biosystems, Imaging and Instrumentation
BME 409: Tissue Engineering and Regenerative Medicine BME 411: BioMEMS BME 413: BioMicro and Nanotechnology BME 415: Bionanomaterials BME 417: Advanced Biofluid Mechanics BME 419: Implantable Systems BME 421: Rehabilitation Engineering BME 423: Human Assist Devices BME 425: Drug Delivery BME 427: Introduction to Medical Robotics BME 471: Pharmaceutical Engineering	CSE 493: Medical Informatics CSE 495: Bioinformatics EEE 377: Random Signals and Processes BME 431: Telemedicine Systems BME 433: Biosensors BME 435: Introduction of Biophysics of Molecules and Cells BME 437: Engineering Optics for Medical Application BME 439: Neural Systems Modeling BME 441: Neural Engineering BME 443: Magnetic Resonance Imaging BME 445: Biomedical Signal Processing BME 449: Machine Learning for Biomedical Engineers

Hum:	10.50 Credits
Math:	15.00 Credits
Physics and Chemistry:	18.00 Credits
BME:	74.50 Credits (including life science of 16.5 credits)
Other Engineering:	27.00 Credits # may vary
Elective:	15.00 Credits
Total:	160.00 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 145: Chemistry - I
3 credits, 3 hours/week

Modern concept of atomic structure, Modern periodic table with special reference to group chemistry, Dual nature of electron and modern concept of chemical bond, Properties and molecular structure, Modern concept of acids and bases. Different types of solutions and their compositions, Theories and Properties of dilute solution, Phase rule, phase diagram of

monocomponent systems, Thermochemistry, Chemical kinetics, Chemical equilibria, Electric properties of solution and electrochemical cells, Buffer, Colloid, Distribution law.

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; MusculoSkeletal 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

English phonetics: the places and manners of articulation of the english sounds; Vocabulary: techniques of enriching stock of words; English grammar: construction of sentences, common grammatical problems; Reading: techniques and strategies for improving comprehension skills, prose pieces by renowned authors; Writing: developing paragraphs as the building blocks of larger discourses; Business correspondence: importance, classifications & structures; Report:

types & layout of reports; Technical writing: research paper, dissertation, thesis, technical proposals, and instruction manual.

Sessional Courses

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

Based on Theory course Phy 123

Chem 146: Inorganic and Physical Chemistry Sessional
1.5 credits, 3 hours/week

Experiments based on Chem 145. (Determination of equilibrium constant, K_c, Cu^{2+} estimation, Fe^{2+} estimation, K_D determination, determination of conc. of HCl by Na_2CO_3, Spectroscopic analysis of Fe^{2+}).

Hum 104: Developing English Skills
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, inferring; analyzing and interpreting variety of texts; practicing comprehension from literary and nonliterary texts; Developing writing skill: Sentences, sentence variety, generating sentences; 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, instruction 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 147: Organic Chemistry
3 credits, 3 hours/week

Hydrocarbons and cyclic hydrocarbons and their derivatives: nomenclature, structure, conformational analysis, and reaction mechanism of Alkanes, Alkenes, Dienes and Alkynes. Substitution, elimination reactions, and their competitiveness on Alkyl Halide. Nomenclature, reaction mechanism, and acid base properties of Alcohol, Ether, Epoxide, and Amine. Reaction mechanism of class I (Ester, Carboxylic Acid, Amides) and class II (Aldehydes, and Ketones), carbonyl compounds.

Stereochemistry: cis-trans (E, Z) isomerism, chirality, nomenclature of enantiomers, Fischer projection and biological selectivity, diastereomers and meso compounds, racemic mixture.

Aromatic: aromaticity, nomenclature of aromatic compounds, and reaction mechanism of Benzenes and substituted Benzenes.

Spectroscopy: IR Spectroscopy, NMR Spectroscopy (1H and 13C) spectroscopy and their application.

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

DC Circuits: basic elements of electric circuits, description and applications of laws, methods and theorems for DC circuit analysis; AC circuits: waves and parameters, average and rms values, instantaneous and phasor response of elements to single-phase sinusoidal excitation; Transient response: capacitive and inductive circuits with DC and AC inputs; Filter circuits: resonance and tuned circuits, basic passive filters; Balanced 3-phase systems: voltage, current and power; Magnetic circuits: magnetic coupling and principle of transformer action.

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; 11 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

Based on Theory course Phy 167

Chem 148: Organic Chemistry Sessional
1.5 credits, 3 hours/week

Synthesis of organic compound and its purification, identification by TLC, Elemental analysis by Lassaigne test, Functional group test, Analysis of spectra (IR, NMR) of synthesized compound.

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

Experiments based on EEE 171

BME 150: Computer Aided Design in Biomedical Engineering Sessional
1.5 credits, 3 hours/week

Designing Biomedical systems using different commercial software packages.

Level 2 – Term I

BME 201: Biomechanics
3 Credits, 3 hours / week

Terminology of movement: reference planes and directions; Principles of equilibrium: forces, moments and couples, equations of static equilibrium; Simple machine: levers and pulleys; Body segment and mass; Center of gravity; Basic statics and movements at specific joints; Linear and angular kinetics and kinematics: kinetic equations of motion, rotations, moment of inertia, radius of gyration, parallel axis theorem; Impulse and momentum; Terrestrial locomotion: jump, kinetics and kinematics of gait cycle; Applications of human motion analysis; Mechanics of deformable bodies: simple stress and strain, Hooke's law, stress- strain diagram, multiaxial deformation and stress analyses, combined stresses, mechanical properties of biological tissues, viscoelasticity; Measurement of mechanical properties of cells; Models of cellular biomechanical behaviour; Skeletal muscle morphology; Muscles constitutive modeling; Muscle and bone interactions; Bone composition, structure and biomechanical properties; Bone fracture and failure mechanics.

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

Introduction to semiconductors. Semiconductor diode: p-type and n-type semiconductors, diode characteristics. Diode applications: half and full wave rectifiers, clipping and clamping circuits, Zener diode and regulated power supply. Bipolar junction Transistor: 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: 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: gain, input and output impedances, linear applications, active filters.

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.

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.

BME 203: Human Physiology
3 credits, 3 hours/week

Introduction to physiology: integrative science of physiology, homeostasis; Endocrine system: hormones, classification of hormones, control of hormone release; Central nervous system: organization of the nervous system spinal cord, brain; Sensory physiology: general properties of sensory systems, somatic senses, chemoreception: smell and taste, hearing, vision; Efferent motor control: autonomic, somatic; Muscles: skeletal muscle, mechanics of movement, smooth muscle, cardiac muscle; Cardiovascular system: overview, pressure, volume, flow, resistance, cardiac muscle and the heart, heart as a pump; Blood flow and control of blood pressure: blood vessels, blood pressure, regulation of cardiovascular function, exchange at the capillaries; Blood: plasma and the cellular elements of blood, blood cell production, red blood cell, platelets, hemostasis and coagulation; Respiratory system: gas laws, ventilation; gas exchange, regulation of ventilation; Renal system: function of kidneys, kidney function, fluid and electrolyte balance, Digestive system: digestive function and processes, regulation of GI function, Integrated function of cephalic, gastric and intestinal.

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 204 Human Physiology Sessional
1.5 credits, 3 hours/week

Sessional based on BME 203.

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

Experiments based on EEE 273.

BME 202: Biomechanics Sessional
0.75 credits, 1.5 hours/week

Computational solid mechanics for biomedical problems; Simulations of musculoskeletal structure and movement; Gait force analysis using force plate data; Testing of living tissue properties and functions; Lab Project: based on simulation/ experiment.

Level 2 – Term II

BME 211: Bioelectricity
3 Credits, 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; 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; Recent advancements in Bioelectricity.

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

Concept of fluid continuum; Forces acting on a fluid; Properties of fluids; Surface tension; Statics of fluids; 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, dynamic similarity, dimensionless numbers, viscoelastic and viscoplastic property; Control volume analysis: mass and momentum balance, continuity and momentum equations; Bernoulli's principle; Newton's law of viscosity; Navier-Stokes equations; Poiseuille flow; Pulsatile flow in rigid and elastic tube; Basic Hemodynamics: hematology and blood rheology; Compliance, inertance and resistance in blood vessels; Multiphase flow; Micro and macrocirculation: Fahreus- Lindqvist effect, hemodynamics in

vascular diseases; Respiratory flow: pressure-volume relationship; Assistive and implantable devices;

Basic modes of heat transfer; Heat Transfer in Biological Systems; Thermal regulation of human body; Thermal injury; Therapeutic applications of bioheat transfer; 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, combinational logic circuits; Arithmetic and data handling logic circuits, decoders and encoders, multiplexers and demultiplexers; Flip-flops, Counters, Registers; Sequential logic circuits.

Digital Electronics: Diode 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; 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 IRn to IRm. Properties of' linear transformations from IRn to IRm. 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.

BME 207: Biomaterials
3 credits, 3 hours/week

Introduction to biomaterials: structure and properties of metals, polymers (natural and synthetic), ceramics and glasses, composites.; Machining of biocompatible materials: conventional and non-conventional machining; Fabrication methods: additive manufacturing, spinning, particle synthesis, hydrogel.

Characterization techniques: scanning electron microscopy, transmission electron microscopy, fourier transform infrared spectroscopy (FTIR), x-ray diffraction (XRD), energy dispersive x-ray spectroscopy (EDS), tensile testing, thermal analysis; Biocompatibility: biomaterials-tissue interaction, wound healing and foreign-body response, blood clotting and blood-biomaterial interaction, protein-biomaterial interaction; Applications of biomaterials.

Sessional courses

BME 210: Numerical Techniques Sessional
0.75 credits, 1.5 hours/week

Laboratory on numerical techniques using computer solutions of differentiation and integration problems, solving a system of linear equations, curve fitting, Numerical solution of linear and nonlinear ordinary differential equations: Runge- Kutta method; Numerical solution of partial differential equations: finite difference method; Optimization.

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.

BME 208: Biomaterials Sessional
1.5 credits, 3 hours/week

Experiments based on BME 207.

Level 3 – Term I

BME 309: Quantitative Physiology
3 credits, 3 hours/week

Introduction to physiology; The action potential; Skeletal muscles dynamic response; Cardiovascular system: review and pathophysiology, the cardiac function curve, hemodynamics, microcirculation and solute exchange, perfusion regulation, cardiac output and venous return, arterial pressure regulation; Respiratory system: review and pathophysiology, lung mechanics, lung volumes and airway resistance, gas exchanges in the lungs, oxygen and carbon dioxide transport, bicarbonate buffer system, respiratory compensation; Renal system: review and pathophysiology, body fluid compartments, kidney function, glomerular filtration, tubular reabsorption and secretion, fluid and electrolyte balance, renal component of acid-base balance; Endocrine system: review and pathophysiology, general principles of endocrinology, control of blood glucose.

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

Basic concepts of medical instrumentation: principles and properties of a medical instrumentation and measurement system; Basic sensors and principles: biophysical parameters, transducers; Biopotential electrodes and amplifiers: polarization, circuit models, interface between skin and electrodes, motion artifacts techniques, grounding, shielding; Body surface potential: EOG, electroretinogram, electrocochleogram; Biosensors: ion selective and immunologically sensitive field effect transistors, non-invasive blood gas monitoring, electronic noses; Cardiovascular measurements: photoplethysmography, arrhythmia monitor, QRS detection techniques, exercise stress testing, cardiotocograph, methods of monitoring fetal heart rate and labour activity; Measurement of respiratory volumes and flow: impedance pneumography; Measurement of pressure, flow and volume of blood: direct measurements and analysis of blood pressure, measurement of system response, bandwidth requirement for measurement, PCG, tonometry, indicator dilution method, electromagnetic flowmeters, ultrasonic flowmeters, thermal convection velocity sensors; Therapeutic and prosthetic devices: ventilator, inhaler, defibrillator, pacemaker, neural simulator, respirator, heart lung machine; Clinical laboratory instrumentation: electrophoresis, hematology; Electrical safety: physiological effects of electricity, macro and micro shock hazards, electrical safety codes and standards, protection for power distribution and equipment design.

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

Basic concepts of biosignal: biosignals and their non-deterministic properties, models of biomedical systems, Representation of signals: 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, the order of the system, solution techniques, zero state and zero input response, system properties, impulse response-convolution integral, determination of system properties, State variable: basic concept, state equation and time domain solution; Models of physiological systems: model of blood flow, fluid, mechanical and electrical system analog, the electrical model of the coronary circulation; Frequency domain analysis of LTI systems: Fourier series- properties, harmonic representation, system response, the frequency response of LTI systems, Fourier transformation- properties, system transfer function, system response, 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; Filter Design: 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, prototyping and demonstration.

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

BME 317: Biochemistry for Biomedical Engineers
3 credits, 3 hours / week

Proteins: amino acid sequences, primary, secondary, tertiary and quaternary structure; classification of proteins; Enzyme kinetics: mechanism and regulation; Bioenergetics: the role of ATP, biological oxidation, respiratory chain, phosphorylation; Carbohydrates metabolism: citric acid cycle, glycolysis, oxidation of pyruvate, gluconeogenesis and the control of blood glucose, glycogen metabolism; Lipid metabolism: dietary lipid metabolism, fatty acid metabolism, triacylglycerol metabolism, ketone body metabolism, cholesterol metabolism, lipoprotein metabolism, steroid metabolism; Protein and amino acid metabolism: nitrogen disposal, degradation and synthesis, conversion to specialized products; Heme metabolism; Integration of metabolism: metabolism effect of insulin and glucagon, the fed-fast cycle, diabetes mellitus, obesity; Special topics: nutrition, vitamins and minerals, free radicals and antioxidants, metabolism of xenobiotics; Clinical biochemistry.

BME 305: Biomedical Control Systems
3 credits, 3 hours / week

Introduction to modeling: what is a model and why model, modeling physical systems; Multi-scale organization of living organisms: cell to organ homeostasis; Examples of biomedical control systems: physiological systems and medical robotics; 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 control systems, design of PID controllers; Modeling of cardiovascular systems: blood pressure and flow, vascular impedance, lumped parameter models, Windkessel model of circulation, cardiac mechanics; Modeling of endocrine system: enzymes and hormones, Michaelis-Menten enzyme kinetics, examples of endocrine control- glucose insulin system, thyroid hormone system; Modeling of nervous system; Modeling of respiratory system: respiratory mechanics, lung models; Modeling of musculoskeletal system: 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; Applications to medical robotics: prostheses and artificial limbs, orthotic devices and exoskeleton, robot assisted surgery, haptic technology, soft robotics.

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

Introduction to mass, momentum and heat transport in living systems; Conservation relations: mass, momentum and energy balance; Navier- Stokes equation; Passive scalar transport; Dimensional analysis and scaling; Low reynolds number flow; Integral form of the conservation equations; Boundary layer theory; Peristaltic pumping; Flow in circulation and tissues; Basic molecular mechanics of fluid and electrolyte transport across cell membranes and epithelia; 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; Reaction and enzyme kinetics; Mass transfer in kidney dialysis; Compartmental models for pharmacokinetic analyses; Analysis of blood oxygenators; Heat transport: unsteady state heat transfer, heat transport by convection; Theoretical determination of thermal properties for biomaterials.

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

Introduction to digital signal processing; Sampling and signal reconstruction; Analysis of discrete-time systems 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.

BME 313: Molecular Biology and Immunology
3 credits, 3 hours / week

DNA and chromosomes: structure, regulation, DNA replication, repair and recombination from DNA to protein, control of gene expression; Modern recombinant DNA technology: manipulating and analyzing DNA molecules, DNA cloning in bacteria, DNA cloning by PCR, exploring and exploiting gene function; Membrane structure: the lipid bilayer, membrane proteins; Transport across cell membranes: transporters, ion channel, nerve cell signaling, intracellular compartments and protein transport; Cell signaling: general principles, G-protein-coupled receptors, enzyme-coupled receptors; Introduction to the immune system: properties and overview of immune responses, innate immunity, cells and tissue of the adaptive immune system; Recognition of antigens: antibodies and antigens, major histocompatibility complex, antigen processing and presentation to T lymphocytes, maturation, activation and regulation of

lymphocytes; Effector mechanism: cytokines, effector mechanism for cell-mediated and humoral immunity.

Sessional courses

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

Hands-on experience in integrated medical device innovation cycle including clinical needs finding, concept generation and design, implementation, bench-top testing and clinical feasibility study.

BME 306: Biomedical 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 375.

BME 320: Industrial Attachment
1 credit, 3 weeks

The student will be placed in an organization where s/he will gain practical hands-on training on certain topics of BME. The organization will be in the medical equipment manufacturing / assembling industry, hospital, clinic, and so on. The student will be evaluated by the course teacher based on evaluation and feedback of the attached organization.

Level 4 – Term I

Hum 445: Sociology
3 credits, 3 hours / week

Sociology: 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 441: Engineering Economics
3 credits, 3 hours / week

Economics and engineering; Microeconomics and macroeconomics; Theory of demand and supply and their elasticities; Demand estimation; Price determination; Indifference curve technique; Theory of production; Theory of cost and cost estimation; Market structure; National income accounting; Depreciation; Circular flow of income and expenditure; Major Macroeconomic policy issues; Cost-benefit analysis; Payback period; Net present value (NPV); Internal rate of return (IRR); Inflation; Economic feasibility of engineering undertakings; Development economics.

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

Introduction to medical imaging: medical imaging modalities, medical imaging before x-rays; Hippocratic thermography; Dissection; Laparoscopy; 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
3 credits, 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 447: Clinical Engineering
3 credits, 3 hours / week

Clinical Engineering: major aspects of clinical engineering; The role of clinical engineers in hospital: clinical engineering activities, patient focused engineering; Clinical measurements; Medical devices and their working principles: external defibrillators, anesthesia machines, EKG/ECG, patient monitors, nebulizers, spirometer, electrosurgical devices, mechanical ventilation; Mobility and wheelchair assessment; Mechanical and electromechanical devices: prosthetics, orthotics, arm supports; Medical engineering design: regulations, quality assurance, safety and risk management; Clinical ethics; Management of medical equipment.

Elective Courses

BME 409: Tissue Engineering and Regenerative Medicine
3 credits, 3 hours / week

Fundamentals of tissue engineering; Cells: cell culture basics, primary cells, cell lines; Stem cells: different types of stem cells, potency of stem cells, iPSC, stem cell based therapy; Scaffolds: ECM, dECM, synthetic scaffolds/ECM, scaffolds manufacturing technology, cell encapsulation, organ printing; In vitro control of tissue development: bioreactors, growth factors, mechanical cues; Lab-on-a-chip; Tissue engineering of different tissue systems: cardiovascular, skin, bone, liver; Regenerative medicine; Clinical translation.

BME 411: BioMEMS
3 credits, 3 hours / week

Introduction to BioMEMS: sensors-actuator mechanisms for BioMEMS, biocompatibility, reliability and regulatory considerations, silicon microfabrication, soft fabrication and polymers, micropatterning of substrates and cell, surface modification; Microfluidics: transport process, electrokinetic phenomena, microvalves, micromixers, and micropumps; Micro-total-analysis systems (μTAS): lab-on-a-chip, capillary electrophoresis array, cell, molecule and particle handling, microspheres and cell-based bioassays, MEMS for in vivo sensing and electrical impedance spectroscopy for noninvasive measurement of cells, MEMS ultrasonic transducers; BioMEMS for drug delivery and tissue engineering: cell culture microdevices for tissue engineering, micro-scaffolding, drug delivery applications; Genomics and DNA microarrays: introduction to genomics, polymerase chain reaction, gene expression profiling, DNA microarrays, pharmacogenomics; Emerging applications of BioMEMS: implantable neuroprobes, ocular implants, minimally invasive surgery, endoscopy, ophthalmology, cardiovascular and dermabrasion applications, etc.

BME 413: BioMicro and Nanotechnology
3 credits, 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 and characterization: nanoscale lithography, non-lithography-based vs lithography-based manufacturing, etch processes- wet etching and dry etching, chemical vapor deposition- APCVD, SACVD, LPCVD, UHCVD, PECVD, MOCVD, ALD, physical vapor deposition- thermal evaporation, sputtering, thermoforming, Micromolding Techniques- LIGA, scanning probe microscopy, atomic force microscopy, scanning electron microscopy, transmission electron microscopy; Structural and functional principal of bionanotechnology:

self-assembled monolayers, self-assembled bottom-up approaches of nanomaterial growth and top-down paradigm, scaling laws, energetics, chemical transformation, regulation, biomimetic nanostructures, biomolecular motors, micro-actuators, powers and brains in miniature devices; Biomolecular design: intermolecular interaction and molecular recognition, protein folding, recombinant DNA technology, monoclonal antibodies and molecular modeling, gene editing-CRISPR; Current trends and future perspectives.

BME 415: Bionanomaterials
3 credits, 3 hours / week

Introduction: biomedical applications of post CMOS devices, required material properties and its multidisciplinary concepts; Nanomaterials based on conventional nanoelectronics: 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-disulfide 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 and their biological implications; Amorphous coordination polymer particles for biomedicines; Magnetic nanoparticles for drug delivery; Nanomaterial based bioimaging probes; Gold nanostructures for therapy; Molecular 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; 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 blood vessels; 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, applications 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: mechanics of breathing; Biofluid flow in artificial and assistive devices: artificial heart, artificial lung, dialysis machine.

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
3 credits, 3 hours / week

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
3 credits, 3 hours / week

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, biofeedback, ventilator, nebulizer, humidifier.

BME 425: Drug Delivery
3 credits, 3 hours / week

Fundamentals of drug delivery: types of drug release, mechanisms and principles of controlling drug, improving the water solubility and poorly soluble drugs, immediate, delayed, sustained and controlled release delivery systems, basic pharmacokinetics; Parenteral routes for drug delivery and targeting: long acting injections and implants; Non-parenteral routes for drug delivery and targeting: oral drug delivery, buccal and sublingual drug delivery, transdermal drug delivery, nasal drug delivery, pulmonary drug delivery, ophthalmic drug delivery; Emerging technologies: gene delivery, vaccine delivery, and nanofabrication techniques and their application in drug delivery; Nano drug delivery: techniques, chemistry, advantages and challenges.

BME 427: Introduction to Medical Robotics
3 credits, 3 hours / week

Introduction to medical robotics: characteristics and state of art; Medical robotics in the service of patients; Kinematics of medical robotics; Tele-operation; Co-operative manipulation; Robot's dynamics and simulation; Design of medical robots: analysis of gestures, design methodologies, technological choices, security, dependability and risk reduction in medical robotics; Robot guided surgery; Rehabilitation robotics.

BME 471: Pharmaceutical Engineering
3 credits, 3 hours / week

Pharmaceutical Processes: size reduction, size separation, heat transfer, evaporation, distillation, drying, mixing, filtration, and centrifugation; Quality Control: UV-visible spectroscopy, IR spectroscopy, mass spectrometry, NMR spectroscopy, chromatography, thermal methods of analysis, electron microscopy; Quality management: basics of quality management, principles of six sigma, pharmaceutical quality management-ICH Q10, knowledge management, quality metrics, operational excellence, and quality management review, WHO-GMP requirements, QC standards- BP, USP, statistical process control (SPC).

CSE 393: Medical Informatics
3 credits, 3 hours / week

Integration of Information technology and Biomedical Engineering; Introduction to networking, communications, and information infrastructures in the 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
3 credits, 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.

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).

BME 431: Telemedicine Systems
3 credits, 3 hours / week

Introduction to telemedicine. Benefits and limitations of telemedicine. Classification of telemedicine systems. m-Health, e-Health and digital health systems. Communication infrastructure-LAN and WAN technology, circuit and packet switching, medical grade broadband. Satellite, Mobile, Internet technology for telemedicine. Video and audio-conferencing protocols. Communication protocols in telemedicine. Medical information storage and management. Hospital information systems. Functions of DICOM, PACS and HIS in

telemedicine. Different applications of telemedicine: telecardiology, tele-ophthalmology, tele-radiology, telepsychiatry, remote intensive care, tele-dermatology, tele-pathology, home telehealth, emergency telemedicine and telepresence. Innovation and design considerations in telemedicine systems.

BME 433: Biosensors
3 credits, 3 hours / week

Overview of biosensors and transducer fundamentals; Biosensor modeling and theory: variable rate coefficient, fractal analysis, the Mautner Model, analyte capture kinetics, binding and dissociation; Micro and 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 and 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 nanosensors; 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
3 credits, 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
3 credits, 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, combining 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 magnetoencephalogram (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
3 credits, 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, biosensors 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.

BME 449: Machine Learning for Biomedical Engineers
3 credits, 3 hours / week

Introduction to machine learning; Applications in Biomedical Engineering; Types of machine learning; Linear regression; Linear classification; Linear logistic regression; Non-parametric methods; Decision trees; K-Nearest neighbors algorithm; Multi-class Classification; Probabilistic classifiers; Unsupervised clustering; Gaussian mixture model (GMM); K-means clustering;

Performance evaluation measures; Dimensionality reduction: Principal components analysis (PCA); Support vector machines (SVM); Neural networks and Deep Learning; Convolutional neural networks (CNN); Optimization methods; Reinforcement learning.