Proposed BME Postgraduate Program Structure and Course Content

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The Department of Biomedical Engineering
Bangladesh University of Engineering and Technology (BUET)

Courses Offered

Focus Area	Courses offered for M.Sc./M.Engg./Ph.D. in BME
Multidisciplinary	BME 6000: Thesis or Project
	BME 6001: Selected Topics in Biomedical Engineering
	BME 6003: Engineering Principles in Medicine
	BME 6005: Computational Methods in Biomedical Engineering
	BME 6007: Biostatistics
	BME 6009: Drug Development
	BME 6011: Advanced Biophysics
	BME 6013: Advanced Transport Phenomena in Biomedical Engineering
	BME 6015: Biomedical Regulatory Affairs
	BME 6017: Clinical Engineering in Practice
Biomedical Imaging & Instrumentation	BME 6101: Translational Neural Engineering
	BME 6103: Biophotonics
	BME 6105: Hearing and Speech processing
	BME 6107: Biosensors and Biochips
	BME 6109: Biological Microscopic Imaging
	BME 6111: Ultrasound and Photoacoustic Imaging
	BME 6113: X-ray Imaging and Computed Tomography
Biomaterials	BME 6201: Advanced Biomaterials
	BME 6203: Advanced Drug Delivery
	BME 6205: Artificial Organ and Regenerative Medicine
	BME 6207: BioMEMS and Microdevices
Biomechanics	BME 6301: Molecular, Cellular and Tissue Biomechanics
	BME 6303: Fluid Mechanics for Medical Engineering
	BME 6305: Continuum Biomechanics
	BME 6307: Advanced Rehabilitation Engineering
	BME 6309: Computational Fluid Dynamics in Biomedical Systems
Biomedical Informatics	BME 6401: Signal Processing in Biomedical Engineering
	BME 6403: Applied Biomedical and Health Informatics
	BME 6405: Computational Techniques in Systems Biology
	BME 6407: Machine Learning in Healthcare

Detailed Course Contents

BME 6000: Thesis or Project
Thesis (Ph.D. in BME: 45 credits, M.Sc. Engg. in BME:18 Credits) / Project (M.Engg in BME: 6 Credits)

BME 6001: Selected Topics in Biomedical Engineering
3 credits, 3 hours/week

To be determined by the course instructor after approval of the Board of Postgraduate Studies (BPGS) of the Department of BME.

(NB: This course can be taken by a student only once in any program. Any student intending to enroll in the subject BME 6001 in a semester will have to declare in the "Remarks" column of his/her Course Registration form that he/she has not taken this course previously irrespective of the topic title under BME 6001).

BME 6003: Engineering Principles in Medicine
3 credits, 3 hours/week

Biomechanics: introductory mechanics, kinetics and kinematics of human motion, hard and soft tissue, biomechanics of bone, biomechanics of soft tissue, gait and jumping, cellular mechanics; Biofluidmechanics: application of flow concepts and principles, circulatory system, blood pressure, steady and pulsating flow, hemodynamics, description of oxygenator, membrane area based on O2 and CO2 transfer; Transport phenomena: principles of membrane, tissue and vascular transport in biological systems, pharmacokinetic models and transport in bioartificial devices; Medical instrumentation: basic concepts, amplifiers and signal processing, biopotential amplifier circuits, biopotential electrodes, electrical safety; Bioelectric potential and measurements: bioelectric potential, electrocardiogram, electroencephalogram, electromyogram; Medical imaging: basic of imaging equipment, fundamentals of image acquisition, details of different imaging modalities; Computational and system biology.

BME 6005: Computational Methods in Biomedical Engineering
3 credits, 3 hours/week

Modeling biosystems, Linear models of biological systems, Nonlinear equations in biomedical engineering, Finite difference methods, Dynamic systems modeled with ordinary differential equations: Drug pharmacokinetics, cell differentiation, adhesion and migration, glycolysis, membrane and nerve cell potentials; Dynamic systems modeled with partial differential equations: Diffusion across biological membrane, diffusion of macromolecules and controlled release of drugs, cell migration on vascular prosthetic materials and fluid flow in physiological and extracorporeal vessels.

BME 6007: Biostatistics
3 credits, 3 hours/week

Overview of Biostatistics, Biostatistics in research, Ethics in biostatistics, Experiment/clinical trials design, Hypothesis testing, Comparing two proportions, Nonparametric statistical tests, Correlation, Bias and random error, Objectives and endpoints, Sample size and power, Survival analysis, Classification and regression tree, Model validation technique, Repeated measurement analysis, Treatment allocation and randomization, Factorial design, Crossover designs, Meta-analysis, Medical diagnostic testing, Correlation and agreement, Data presentation in general, Introduction to commercial software for biostatistics.

BME 6009: Drug Development
3 credits, 3 hours/week

Basic concepts of drug discovery and testing, Scientific, regulatory, and management framework for modern pharmaceutical development, Preclinical study, Major clinical phases in the drug development process , Economics of drug development, Cost/benefit issues in clinical development, Discovery and development milestones, Investigational new drug application (IND), New drug application (NDA) process, Application review and approval process with the regulatory agency, Patents and exclusivity, Government regulations: Rationale and effect on the development process; Optimal clinical trials design, Drug labeling, marketing, and pharmacoeconomic studies, Project management cross-functional teams during the development process.

BME 6011: Advanced Biophysics
3 credits, 3 hours/week

Atomic and molecular forces in macromolecules, Random walks and the structure of macromolecules, Physics techniques of structure determination using XRD, Spectroscopy, NMR and MRI. Elastic and bending properties of membranes, Models for peptide pathways and the creation of channels in membranes, Vesicles, Membrane-based nanotechnology and drug delivery. Electrostatics of salty solutions. Irreversible electroporation (IRE). Physics of nervous system, Physics of vision and hearing, Physics of muscles. Mechanics of fluids and its application to blood flow. Stochastic processes in biophysics: Master equation, Langevin equation, Fokker Planck equation, Mean first passage time (MFPT). Field theory for stochastic process and derivation of Arrhenius' Law. Information theory for biological networks.

BME 6013: Advanced Transport Phenomena in Biomedical Engineering
3 credits, 3 hours/week

Physical properties of the body fluids and the cell membrane, The physical and flow properties of blood and other fluids, Solute transport in biological systems: Capillary filtration, heterogeneous media, capillary wall, between capillary wall and tissue; Oxygen transport in biological systems, Pharmacokinetic analysis: Drug absorption, distribution, clearance, elimination, compartmental model; Clinical application of transport phenomena: Extracorporeal devices, bioartificial organs and tissue engineering.

BME 6015: Biomedical Regulatory Affairs
3 credits, 3 hours/week

Regulatory Affairs in relation to three key areas of development: Drugs, Biologics, biotechnology-derived therapeutics, vaccines and Medical Devices. The role of regulatory oversight in product design, development and manufacturing, including quality control, scale-up, Good Manufacturing Practices (GMPs) and quality systems, Inspection process and regulatory procedures: Quality System Inspection Technique (QSIT), Post-market surveillance requirements, reporting and enforcement actions. Different regulatory standards.

BME 6017: Clinical Engineering in Practice
3 credits, 3 hours/week

Clinical engineering as applied biomedical engineering, Activities and role of clinical engineers, Good clinical practice: phases of clinical trials, clinical investigations for medical devices, ISO standards; Health

technology management, Medical electronics and measurement, Clinical measurement, Clinical laboratory: separation and spectral methods, non-spectral methods, Medical devices, Essentials of anesthesia delivery, Biomedical lasers, Mobility and wheelchair assessment, Mechanical and electromechanical devices: prosthetics, orthotics, arm supports; Risk factors, safety, regulation and management of medical equipment, Regulatory and assessment agencies, Clinical ethics.

BME 6101: Translational Neural Engineering
3 credits, 3 hours/week

Introduction to Neurosciences, Physiology and anatomy of neurons. Major parts of the brain: brain stem, cerebellum, thalamus, hypothalamus, amygdala, hippocampus and cerebral cortex. Neural recording methods: Microelectrodes, MEMS, optical neural sensors. Neural circuits, amplifiers, telemetry, stimulation. Time-Frequency-Spatial Analysis STFT, Clinical applications of Neural signals: EEG, evoked potentials, Multiple Dimensional Signal Processing, Application in neural systems, EEG/ECoG, BMI- Neural Spikes. Optical imaging: Cellular (microscopy), In Vivo (Speckle, Photoacoustic, OCT), Neuroimaging and Image Processing, Neuroimaging fMRI, Advanced Neurosignal Processing / Neurosurgical systems, Applications of neural signal processing. Brain-machine interfaces (BMIs): Motivations for BMI development. Example applications of BMIs for paralyzed patients and for healthy subjects. Brain-machine interfaces for movement control and communication. Neuronal adaptivity during BMI control.

BME 6103: Biophotonics
3 credits, 3 hours/week

Fundamentals of biophotonics: diverse applications, biophotonics spectral windows, light absorption, signal attenuation, emerging biomedical optical technologies, motivation for optical imaging; Behavior of light in biological tissue: physics of light-matter interaction, absorption, scattering, polarization and fluorescence. Optical fibers for biophotonic applications: overview of optical fibers, double-clad fibers, hard-clad silica fibers, biomedical applications; Light sources: radiometry, arc lamps, light-emitting diodes, lasers for biophotonics, superluminescent diodes; Optical detectors: the pin photodetector, avalanche photodiodes, multichannel detectors, photomultiplier tubes, optical couplers and circulators; Optical probes and biosensors: optical fiber probe, optical sensors, interferometric sensors, photonic crystal fiber biosensors, surface plasmon resonance biosensor. Spectroscopic methodologies: fluorescence spectroscopy, FRET/FLIM, fluorescence correlation spectroscopy, elastic scattering spectroscopy, diffuse correlation spectroscopy; Application of biophotonic instrumentation.

BME 6105: Hearing and Speech processing
3 credits, 3 hours/week

Overview of the neurobiology of hearing, Nature of sound and psychoacoustics, Introduction to the auditory system, Outer, middle and inner ear, Mechano-electrical transduction, Sound localization, Cortical processing: isofrequency maps, receptive fields and plasticity, natural sounds, Vocal learning, Auditory illusions, Auditory models and machine hearing, Hearing aid design, Cochlear implants and brainstem implants, Overview of auditory engineering and speech processing, Linear predictive coding, Pitch models, Physiology of speech production, phases of speech production: respiration, phonation, articulation; Speech pathology: parameters of speech signal, dysphonia measures, voice changes in speech pathology, automatic diagnosis of speech pathology.

BME 6107: Biosensors and Biochips
3 credits, 3 hours/week

Biosensors and biochip technologies, Biosignal Transduction Mechanisms, Challenges of biosensing, Modified electrode, Amperometric sensor, Potentiometric sensor, Biological and molecular recognition

systems: protein recognition in biology, molecular antibody for biosensors, luciferase reporter bacteriophages, natural luminescent whole cell bioreporters; Materials for biosensors, Electrochemical techniques in biosensor, optical biosensing techniques, Thermal and microbiosensor, Microcalorimetry and related techniques, magnetic biosensor, Applications of BioSensors, Lab-on-a-Chip: Microanalytical systems in chemistry and biology, recent trends.

BME 6109: Biological Microscopic Imaging
3 credits, 3 hours/week

Fundamentals of light microscopy, optical components of the light microscope, microscope optics, resolution limits, Köhler illumination, light as particles and waves, properties of light perceived by the eye, physical basis for visual perception and color. Illuminators, filters, and isolation of specific wavelengths, Lenses and geometrical optics: image formation by a simple lens, real and virtual images, rules of ray tracing, object-image math, the principal aberrations of lenses, designs and specifications of objective lenses. Principles of microscope design: image formation, resolution and contrast, transmitted light and fluorescence microscopy techniques; Cameras: signal to noise ratio, digital image recording, processing and analysis, multispectral imaging; Advanced fluorescence: fluorescent probes, fluorescent biosensors, TIRF, FRET, FLIM, FRAP, polarization of fluorescence, fluorescence correlation spectroscopy; Digital image restoration/deconvolution, and 3-D imaging principles, Confocal and multiphoton laser scanning microscopy and light-sheet microscopy, Super-resolution techniques including localization microscopy, Stimulated emission depletion microscopy (STED), Structured illumination microscopy.

BME 6111: Ultrasound and Photoacoustic Imaging
3 credits, 3 hours/week

Fundamentals of ultrasound imaging, wave propagation and characteristic acoustic impedance, wave reflection, refraction and scattering in tissue, absorption and total attenuation of ultrasound energy in tissue, ultrasound instrumentation, single element ultrasound transducers, transducer arrays, Clinical diagnostic scanning modes: A-mode scanning: ophthalmic pachymetry, M-mode echocardiography, two-dimensional B-mode scanning, compound scanning, image characteristics, doppler ultrasound for blood flow measurements, ultrasound elastography, ultrasound contrast agents, safety guidelines in ultrasound imaging, clinical applications of ultrasound: obstetrics and gynaecology, breast imaging, musculoskeletal structure, echocardiography; emerging applications of ultrasound imaging.

BME 6113: X-ray Imaging and Computed Tomography
3 credits, 3 hours/week

Fundamentals of X-ray radiography and CT imaging, X-ray imaging: interactions of X-rays with the body, X-ray planar radiography: the X-ray tube, X-ray linear and mass attenuation coefficients, X-ray detectors, instrumentation for planar radiography, quantitative characteristics of planar X-ray images, X-ray contrast agents, clinical applications of planar X-ray imaging, specialized X-ray imaging techniques: digital subtraction angiography, digital mammography, digital fluoroscopy; Computed tomography (CT): instrumentation for CT, image reconstruction, dual-source and dual-energy CT, digital X-ray tomosynthesis, clinical applications of CT, micro-CT imaging, emerging applications of CT imaging.

BME 6201: Advanced Biomaterials
3 credits, 3 hours/week

Synthesis and properties of metallic, ceramic, polymeric, and biological materials. Hard and soft tissue replacement, Organ replacement, Coatings and adhesives, Dental implants, Drug delivery systems. Recent trends in biomaterials: electrically conductive polymers, piezoelectric biomaterials, smart biomaterials; Biomaterials for tissue engineering, controlled drug and gene delivery, cardiovascular, orthopedic and

artificial organs; Biomaterials associated infections: immunology, antimicrobial strategies.

BME 6203: Advanced Drug Delivery
3 credits, 3 hours/week

Physiological barriers in advanced drug delivery, Solubility and stability aspects in drug delivery, The role of transporters and the efflux system, Biomaterial in advanced drug delivery, Types of drug release, Parenteral and non-parenteral routes for drug delivery, Drug delivery strategies through: bioconjugation, nanoscale drug delivery system, stimuli responsive method, implants, nanofibers, self-assembly nanoparticles, protein and peptide, nucleic acid, vaccine; Specific issues in the delivery of cells and genes, Drug targeting: drug carrier design, passive and active targeting methods, measuring delivery and efficacy; Cancer targeted drug delivery.

BME 6205: Artificial Organ and Regenerative Medicine
3 credits, 3 hours/week

Designing biological tissue and organ substitute. Concepts of tissue development. Histological tissue structures in the body. Basic building blocks of the tissue and clinical need for replacement. Tissue-engineered graft. Biomaterials and bioreactors to regulate the cellular microenvironment. Artificial organ printing. Recent trends in artificial organ printing. Cell-matrix and cell-scaffold interactions, cell-cell interactions and tissue morphogenesis, wound healing, and in vitro organogenesis. Current perspective in regenerative medicine, Diseases impacted by regenerative medicine, Cellular aspects of regenerative medicine: stem cell engineering; Stem cells and their clinical applications: adult stem cell, embryonic stem cells, induced pluripotent stem cells, hematopoietic stem cells.

BME 6207: BioMEMS and Microdevices
3 credits, 3 hours/week

Microfabricated devices designed for biological and medical applications: photolithography, Photolithography: photoresist and photomask, maskless photolithography; Micromachining: etching, laser cutting, multiphoton lithography; Micromolding: injection molding, hot embossing; Soft lithography, Dimensions and scaling challenges in bioMEMS, BioMEMS Materials: silicon to polymers, the need for biocompatibility; Micropatterning of substrates and cells, Microfluidics: microscale behavior of fluids, fluids in electric field, fluids in acoustic field, fabrication of microfluidic channels, droplet microfluidics; Molecular biology on a chip, Cell-based chips, BioMEMS for cell biology: cell substrate signaling, cell-cell communication, cell migration; Tissue microengineering, Implantable microdevices.

BME 6301: Molecular, Cellular and Tissue Biomechanics
3 credits, 3 hours/week

The structure of tissues and the molecular basis for macroscopic properties; chemical and electrical effects on mechanical behavior; cell mechanics: cell shapes, size and structures, forces inside and outside of the cell, filaments and associated two and three dimension networks, structural component of cell and filaments; motility and adhesion; biomembranes; biomolecular mechanics and molecular motors. Experimental methods for probing structures at the tissue, cellular, and molecular levels.

BME 6303: Fluid Mechanics for Medical Engineering
3 credits, 3 hours/week

Principles of fluid mechanics with applications to flow systems of medical engineering, Macrocirculation: Pulsatile blood flows in arteries, bifurcation, veins and curved vessel; flow behavior in flexible vessels; Analysis of arterial disease: atherosclerosis and aneurysm, Microcirculation: Pressure and velocity

distribution in microvascular beds: arterioles and venules, capillaries, lymphatics; Fahraeus-Lindquist effect, Interaction of red blood cells with vessel walls. Biofluid dynamics in human organs: Heart, lungs, kidneys, liver, urinary, brain and intraocular system; Fluid mechanics in assistive and implantable medical devices: blood pump, blood oxygenator, artificial heart, prosthetic heart valve, artificial lung, dialysis machine, cardiovascular stent; Drug delivery in microvessels, Application of microfluidics and bioMEMs in medial engineering.

BME 6305: Continuum Biomechanics
3 credits, 3 hours/week

Introduction to conservation laws and thermodynamic principles of continuum mechanics with application to tissues of the musculoskeletal and cardiovascular systems, Nonlinear and anisotropic behaviors of solids and fluids, Application of hyperelastic constitutive formulations to determination of stress and strain fields in deformations of calcified tissues (for example, cortical and trabecular bone), soft tissues (for example, ligament, cartilage, cornea, intervertebral disc, left ventricle, aorta), and biological fluids (for example, mucus, synovial fluid, polymer solutions).

BME 6307: Advanced Rehabilitation Engineering
3 credits, 3 hours/week

Overview of rehabilitation engineering, Assistive technologies, patent issues, engineering ethics, Rehabilitation of injured and amputee persons: orthosis, prosthetics; Rehabilitation engineering design: design considerations, total quality management in rehabilitation engineering, universal design and accessibility, barrier free design, elemental resource model, factors affecting barrier free design; Rehabilitation of visual, hearing and tactile function, Rehabilitation of vestibular and vegetative functions, Brain stimulator and recording, Robots in Rehabilitation Engineering.

BME 6309: Computational Fluid Dynamics in Biomedical Systems
3 credits, 3 hours/week

Theory of computational techniques for predicting fluid flow and heat and mass transfer, Introduction to advanced CFD codes: Geometry modeling, mesh generation, solution strategy, and post-processing; Application of computational fluid dynamics in biomedical engineering, Uncertainty of numerical results: Sources of uncertainties, Independence studies on grid, time-step, domain and initial condition; Introduction to commercially available software, Development of customized physical models.

BME 6401: Signal Processing in Biomedical Engineering
3 credits, 3 hours/week

Overview of biomedical signals, review of signals and systems. Advanced Tools for Biomedical Signal Processing: sampling, Fourier transform, filtering, stochastic signals correlation, and power spectral density, short-term Fourier transform, time-frequency distributions, Cohen's class, wavelet transform, autoregressive models, linear prediction, parametric spectral estimation, criteria for model selection, adaptive filtering, adaptive prediction, adaptive estimation of transfer functions, adaptive interference cancellation, polynomial models, singular value decomposition, principal component analysis, empirical mode decomposition (EMD), blind source separation, deconvolution, application of advanced signal processing tools for analyses of electrocardiogram (ECG), electroencephalogram (EEG), electromyogram (EMG), electrooculogram (EOG), magnetoencephalogram (MEEG), respiratory and heart sounds. Overview of biomedical image processing, Image segmentation and registration: statistical classification, morphological operators, connected components, rigid and non-rigid transformations, objective functions, joint entropy, optimization methods, application of image segmentation process in clinical MRI, CT images, ultrasound etc., co-registration of medical images.

BME 6403: Applied Biomedical and Health Informatics
3 credits, 3 hours/week

Overview of biomedical Informatics: grand challenges in biology, medicine and healthcare, importance of information technology. Biomedical data: types and characteristics of biological, medical and health data, distributed data systems, acquisition, transmission, processing, storage and retrieval of biomedical data, standards; Biomedical decision making: probabilistic clinical reasoning, expected-value decision making, sensitivity analysis, influence diagrams; Biomedical imaging informatics: imaging modalities, semantic and quantitative information in images, image registration, image fusion; Design of biomedical informatics systems, Natural language processing in healthcare, Ethics in biomedical and health informatics, Health information infrastructure Patient monitoring systems: bedside physiological monitors, computerized decision support systems, current challenges. Remote health monitoring: telehealth, electronic health records (EHR), personalized health (pHealth), wearable and/or implantable systems, internet of things (IoT) and ubiquitous for health, body sensor/area networks, mobile health (mHealth) systems; Public health informatics.

BME 6405: Computational Techniques in Systems Biology
3 credits, 3 hours/week

Computational Molecular Biology: Biological sequences and sequencing methods, Sequence repositories, Sequence searching and alignment, The Basic Local Alignment Search Tool (BLAST), Protein structure and domains, Structure searching and alignment, Genome assembly, Genome annotation, Genetic variations, Genotype/phenotype correlations, Gene and protein expression, analysis and datasets, Networks and pathways, Regulatory Network inference, Phylogenetics; Computational Cell Biology: Models of Population Dynamics using Recursion Relations, Biochemical Kinetics, Neuronal Modeling, Cell Cycle Modeling, Compartmental Models, Stochastic models; Protein Modeling: Protein Modeling Questions, Models of Proteins, Discrete Conformational Search, Binding and Docking, Molecular Dynamics Simulation, Molecular Dynamics and Electrostatics, Continuum Electrostatic Modeling, Electrostatic Optimization and Design, Electrostatics Modeling, Statistical Mechanics. Network Modeling: Formulating and Simulating Network Models in Biology, Formulating Models, Nonlinear Dynamics and Stability, Steady-State Problems, Parameter Fitting and Estimation, Parameter Estimation; Robustness, Fragility, Control.

BME 6407: Machine Learning in Healthcare
3 credits, 3 hours/week

Overview of machine learning and its applications in healthcare, Classification: fundamentals of classifiers, logistic regression, evaluation metrics, linear regression for prediction and forecasting, case study: predicting hypertension from sleep apnea index; Supervised and unsupervised methods: feature selection, model overfitting problem, dimensionality reduction, unsupervised clustering, case study: automatic speech pathology. Deep learning: single and multi-layer perceptron, activation function, stochastic gradient descent, the backpropagation algorithm, hyper-parameter tuning, parameter initialization, optimization methods, batch normalization, regularization techniques, convolutional neural network (CNN), case study: arrhythmia detection, diabetic retinopathy detection. Sequence modeling: recurrent neural network (RNN), long-short-term memory (LSTM), case study: adverse drug event tracking in electronic health records (EHR).