

Proposal for the Biomedical Engineering Curriculum in UET Lahore (KSK Campus)

FRAMEWORK/TEMPLATE FOR BE/BS IN BIOMEDICAL ENGINEERING

Duration	4 years
Number of semesters:	8
Number of weeks per semester:	16-18 (16 for teaching and 2 for examinations)
Total number of credit hours:	131
Number of credit hours per semester:	14-18
Engineering Courses (Minimum):	71%
Non-Engineering Courses (Maximum):	29%

Summary				
Domain	Knowledge Area	Total Courses	Total Credits	% Overall
Non-Engineering	Humanities	7	14	29.01
	Management Sciences	1	3	
	Natural Sciences	6	18	
	Computing	1	3	
	Sub Total	15	38	
Engineering	Engineering (Foundation)	10	37	70.99
	Major Based Core (Breadth)	7	27	
	Major Based Core (Depth)	6	21	
	Interdisciplinary Engineering and Technical Electives	2	2	
	Senior Year Project	2	6	
	Sub Total	27	93	
Grand Total		42	131	100

Scheme of Studies for BE/BS (4 Years) in Biomedical Engineering

First Semester				Second Semester			
Course Title	Lec	Lab	CR	Course Title	Lec	Lab	CR
Applied Physics (PHY-123)	2	1	3	Applied Electricity (EE-199)	3	1	4
Introduction to Computing (CS-141)	2	1	3	Communication Skills (HU-111L)	0	1	1
Calculus (MA-123)	3	0	3	Applied Chemistry (CH-100)	2	1	3
Basic Biology (BME-141)	3	1	4	Differential Equations (MA-228)	3	0	3
International Language (Audit course)	0	0	0	Human Physiology & Anatomy (BME-131)	3	1	4
Engineering Drawing (ME-124L)	0	1	1				
Total	10	4	14	Total	11	4	15

Third Semester				Fourth Semester			
Course Title	Lec	Lab	CR	Course Title	Lec	Lab	CR
Modeling of Physiological Processes (BME-252)	3	1	4	Cell and Molecular Biology (BME-243)	3	1	4
Biomaterials & Design (BME-251)	3	1	4	Numerical Methods (MA-346)	3	0	3
Biochemistry (BME-242)	3	0	3	Signals & Systems (EE-220)	3	0	3
Technical Writing and Presentation Skills (HU-221)	3	0	3	Biophysics (BME-211)	3	1	4
Linear Algebra (MA-234)	3	0	3	Digital Systems (EE-272)	3	1	4
Work Shop Practice (ME-100L)	0	1	1				
Total	15	3	18	Total	15	3	18

Fifth Semester				Sixth Semester			
Course Title	Lec	Lab	CR	Course Title	Lec	Lab	CR
Islamic/Ethics & Pak Studies 1 (IS-101)	3	0	3	Biomedical Signal Processing (BME-321)	3	1	4
Biomechanics (BME-312)	3	1	4	Clinical Laboratory Instrumentation (BME-333)	3	1	4
Applied Probability (EE-302)	3	0	3	Islamic/Ethics & Pak Studies 2 (IS-201)	3	0	3
Microprocessor Systems (EE-273)	3	1	4	Electromagnetic Theory (EE-380)	3	0	3
Biomedical Instrumentation (BME-332)	3	1	4	Tissue Engineering (BME-352)	3	1	4
Total	15	3	18	Total	15	3	18

Seventh Semester				Eighth Semester			
Course Title	Lec	Lab	CR	Course Title	Lec	Lab	CR
Management Elective (MGT-4XX)	3	0	3	Technical Elective 2 (BME-4YY)	3	1	4
Technical Elective 1 (BME-4XX)	2	1	3	Biomedical Imaging (BME-422)	3	1	4
Control Systems (EE-340)	3	1	4	Technical Elective 3 (BME-4ZZ)	2	0	2
Biomedical Engineering Project 1 (BME-499a)	0	3	3	Biomedical Engineering Project 2 (BME-499b)	0	3	3
Social & Ethical Aspects in Engineering (IME-251)	2	0	2	Clinical Psychology (HU-4XX)	2	0	2
Total	10	5	15	Total	10	5	15

Internship:

A hospital/industry internship after the completion of sixth semester should be mandatory during summer as part of the degree requirement.

1 Knowledge Area – Humanities (14 Credit Hours)			
Course No	Title	Hours	
		Th	Lab
HU-111	Communication Skills	0	1
HU-221	Technical Writing and Presentation Skills	3	0
IS-101	Islamic and Pak Studies/Ethics 1	3	0
IS-201	Islamic and Pak Studies/Ethics 2	3	0
HU-151	International Language	0	0
HU-4XX	Clinical Psychology	2	0
IME-251	Social and Ethical Aspects in Engineering	2	0

2 Knowledge Area – Management (3 Credit Hours)			
Course No	Title	Hours	
		Th	Lab
MGT-4XX	Management Elective	3	0

3 Knowledge Area – Natural Sciences (18 Credit Hours)			
Course No	Title	Hours	
		Th	Lab
PHY-123	Applied Physics	2	1
CH-100	Applied Chemistry	2	1
MA-123	Calculus	3	0
MA-228	Differential Equations	3	0
MA-234	Linear Algebra	3	0
MA-346	Numerical Methods	3	0

4 Knowledge Area – Computing (3 Credit Hours)			
Course No	Title	Hours	
		Th	Lab
CS-141	Introduction to Computing	2	1

5 Knowledge Area – Engineering Foundation (37 Credit Hours)			
Course No	Title	Hours	
		Th	Lab
BME-141	Basic Biology	3	1
BME-131	Human Physiology & Anatomy	3	1
BME-242	Biochemistry	3	0
EE-272	Digital Systems	3	1
BME-211	Biophysics	3	1
EE-302	Applied Probability	3	0
EE-273	Microprocessor Systems	3	1
EE-199	Applied Electricity	3	1
EE-380	Electromagnetic Theory	3	0
BME-252	Modeling of Physiological Processes	3	1

6 Knowledge Area – Major Based Core (Breadth) (27 Credit Hours)			
Course No	Title	Hours	
		Th	Lab
EE-220	Signals & Systems	3	0
BME-312	Biomechanics	3	1
BME-251	Biomaterials & Design	3	1
BME-422	Biomedical Imaging	3	1
EE-340	Control Systems	3	1
BME-243	Cell & Molecular Biology	3	1
BME-332	Biomedical Instrumentation	3	1

7 Knowledge Area – Major Based Core (Depth) (21 Credit Hours)			
Course No	Title	Hours	
		Th	Lab
BME-321	Biomedical Signal Processing	3	1
BME-352	Tissue Engineering	3	1
BME-333	Clinical Lab Instrumentation	3	1
BME-4XX	Technical Elective 1	2	1
BME-4YY	Technical Elective 2	2	1
BME-4ZZ	Technical Elective 3	2	1

8 Knowledge Area – Interdisciplinary (2 Credit Hours)			
Course No	Title	Hours	
		Th	Lab
ME-100L	Workshop Practice	0	1
ME-124L	Engineering Drawing	0	1

9 Knowledge Area – Senior Design Project (6 Credit Hours)			
Course No	Title	Hours	
		Th	Lab
BME-499a	Final Year Project (Phase 1)	0	3
BME-499b	Final Year Project (Phase 2)	0	3

List of Technical Electives: (3 out of given 7 must be chosen)

1. *BME-413-Rehabilitation and Sports Medicine (2+1)*
2. *BME-414-Biomedical Robotics (2+1)*
3. *BME-415-Biofluid Mechanics (2+1)*
4. *BME-416-Electromechanical Technology (2+1)*
5. *BME-423-Telemedicine & Medical Informatics (2+1)*
6. *BME-424-Neuroscience & Neural Networks (2+1)*
7. *BME-444-Genetic Engineering (2+1)*

List of Management Electives: (1 out of given 4 must be chosen)

1. *MGT-313-Total Quality Management (3+0)*
2. *MGT-410-Project Management (3+0)*
3. *MGT-414-Entrepreneurship and Business Management (3+0)*
4. *MGT-460-Engineering Economics (3+0)*

Semester 1

PHY-123_ Applied Physics: (2+1)

Elasticity; modulus of Elasticity, Experimental determination of young's modulus, Bending of beams, Cantilever. Steady and turbulent flow, Bernoulli's theorem, Viscosity, determination of Coefficient of viscosity. Surface tension, Surface energy, Angle of contact, determination surface tension by rise in a capillary tube. Heat, Temperature, Theories of heat, Adiabatic and isothermal processes, the four laws of thermodynamics, Thermodynamic functions, Efficiency of Heat Engines, Carnot's Cycle, Entropy, Reversible Process and cycles, Thermodynamic equilibrium, Introduction to Heat Transfer Mechanisms. Waves and Oscillations, Simple Harmonic Motion, types of wave motion, theories of light, Interference, Diffraction, Polarization, Double refraction, Dispersion, Types and uses of Deviation Lasers. Electric charges, Electric field, Electric potential, Coulomb's law, Gauss's law, Capacitors and dielectrics, Electric current, Ohm's Law, Magnetic properties of matter, Magnetic field, Magnetic force on current, Ampere's law, Faraday's law, and Lenz's law

Recommended Books:

- 1) Applied Physics by Dale Ewen, Edition 11th, Pearson, 2016
- 2) Physics: Principles with Applications by D C Giancoli, Edition 7th, Pearson/Prentice Hall, 2013
- 3) Schaum's Outline of Applied Physics by Arthur Beiser, Edition 4th, McGraw Hill, 2004

CS-141_ Introduction to Computing: (2+1)

An overview of Computer Science and information technology with applications. Number systems and Boolean algebra. Basic programming concepts. Arrays and strings. Advanced Programming Concepts: data types, pointers and references, parameters passing, functions, classes, objects, headers and file linkages. Filing & Interfacing: File handling, input output interfacing. Graphics: Drawing functions, graphic modes. Applications: Development of software for solving biomedical problems

Recommended Books:

- 1) Introduction to Computing systems: From bits and gates to C and Beyond by Y N Patt, Edition 2nd, McGraw Hill Education, 2003
- 2) Introduction to Computing: Explorations in Language, Logic and Machines by D Evans, Edition XX, Create Space Independent Publishing Platform, 2011
- 3) Fundamentals of Data Structures in C, by Sahni, Edition 2, Computer Science Press, 2008

MA-123_Calculus: (3+0)

The topics covered include: Review of functions and limits, differentiation, applications of derivatives, integration, techniques of integration, vectors and the geometry of space, vector-valued functions and motion in space, partial derivatives and multiple integrals in vector fields.

Recommended Books

- 1) Thomas' Calculus, by George B Thomas Jr., Maurice D. Weir and Joel R. Hass, Edition 13th, Pearson, 2014
- 2) Calculus by Ron Larson and Bruce H. Edwards, Edition 10, Brooks Cole, 2013.

BME-141_Basic Biology: (3+1)

Biology, Major branches of biology, Three Domains of life. Prokaryotes and Eukaryotes. Chemistry of biomolecules, Cell structure and division including mitosis and meiosis, Tour of the cells and its organelles. Central dogma of Molecular Biology, Chromosomes and DNA, genes, units of heredity, Genes & alleles. Mendel's laws of inheritance, multiple alleles, linkage and crossing over, sex determination, Viruses and Infectious diseases, Immune system, Cell signaling and communication. Recombinant DNA technology, Development and role of cytoplasm and nucleus in development, Cancer

Recommended Books:

- 1) Life, The Science of Biology by David E Sadava, Edition 10th, W H Freeman and Co, 2012
- 2) Molecular Biology of the Cell by Bruce Alberts, Edition 6th, Garland Science, 2014
- 3) Campbell Biology by Jane B Reece, Edition 10th, Pearson, 2013

Audit Course_International Language: (0+0)

University Core. Introduction and basics of any of the international language. This course is university's prerequisite for the award of degree. The choice of language can be from Arabic and Chinese. Teacher concerned will device the optimum book for the teacher of the language.

Recommended Books: (By Concerned Department)

ME-124L_Engineering Drawing: (0+1)

The objective of this course is to equip the students with the basic knowledge and skills of engineering drawing and its application in practical scenarios. The students will also be introduced to a CAD package (such as Solid Edge, Pro-E). Topics to be covered include: types of lines and usage, dimensioning, lettering, orthographic first angle projection, sheet planning, orthographic third angle projection, introduction to computer aided drawing, isometric projection, sectional drawing and assembly drawing. Drawing sheets will be prepared on drawing board as well as CAD package.

Recommended Books:

- 1) Tutorial Guide to AutoCAD 2014, by Shawna Lockhart, Edition 1, SDC Publications, 2013
- 2) First Year Engineering Drawing, by A. C. Parkinson, Edition 1, Isaac Pitman, 1944

Semester 2

EE-199_Applied Electricity: (3+1)

Basic Concepts, Electrical Quantities and Units, Basic Circuits, Laws and Measurements, Circuit Components, Multiple-Load Circuits, Complex-Circuit Analysis, Magnetism and Electromagnetism, Alternate Current and Voltage, Power in AC Circuits, Capacitance, Inductance, Transformers, R, C, and L Circuits, Electric Motors, Instruments and Measurements, Residential Wiring Concepts.

Recommended Books:

- 1) Electricity: Principles and Applications, by Richard Fowler, Edition 8th, McGraw Hill, 2012.
- 2) Electrical Engineering: Concepts and Applications, by S. A. Reza Zekavat, Edition 1, Prentice Hall, 2012

HU-111_Communication Skills: (0+1)

This is a practical course that offers an opportunity to learn, apply and practice principles of interpersonal communication in daily life. Emphasis is placed on psychological, social, cultural and linguistic factors that affect both interpersonal and inter-organizational dealings.

Recommended Books:

- 1) Lesikar's Business Communication: Connecting in a Digital World, by Raymond V. Lesikar, Edition 13th, McGraw Hill, 2013
- 2) Communication Skills Training (Positive Psychology Coaching Series Books) by Ian Tuhovsky and Wendell Wadsworth, Edition 1, Createspace Independent Publishing Platform, 2015.

CH-100_Applied Chemistry: (2+1)

Wave properties of electrons and matter Quantum theory of matter at atomic level, atomic structure. Energy levels, orbital, hydrogen spectrum, bond energy, molecular structure and its rotational and vibration energy. Types of Bonds, Hybridization and Theories of Bonding. Valence Shell Electron Pair Repulsion Theory and Molecular Orbital Theory. Gas laws, properties of liquid, surface tension, viscosity, optical activity, dielectric constant, polarization, dipole moment. Crystal structure. Rate of reaction, order of reaction, First, Second and third order reaction, factors affecting rate of reaction like Pressure, Temperature, concentration, catalyst, surface area and volume. Oxidation and reduction reactions, Balancing of redox reaction in acidic and basic medium. Construction of galvanic cell. Introduction and classification of organic compounds. Saturated and unsaturated hydrocarbons. Chemistry of Alkanes, Alkynes, Alkenes and Aromatics. Nucleophilic and Electrophonic Substitution Reactions.

Recommended Books:

- 1) Applied Chemistry: A text book for engineers and technologists by O Roussak, Edition 2nd, Springer, 2013
- 2) Elements of General, Organic and Biological Chemistry by John, R. Holum. Edition 9, John Wiley & Sons, 1995
- 3) Chemistry, The Central Science by Theodore E Brown, Edition 13th, Pearson, 2014

MA-228_Differential Equations: (3+0)

(Pre-Requisite: Calculus)

The course covers: Some Basic Mathematical Models, Direction Fields, Classification of Differential Equations, First Order Differential Equations, Second Order Linear Equations, Higher Order Linear Equations, Series Solutions of Second Order Linear Equations, Laplace Transform, Systems of First Order Linear Equations, Numerical Methods, Runge-Kutta Method, Nonlinear Differential Equations and Stability, and Partial Differential Equations.

Recommended Books:

- 1) Elementary Differential Equations and Boundary Value Problems, by Boyce and Diprima, Edition 10th, Wiley, 2012
- 2) Schaum's Outline of Differential Equations by Richard Bronson and Gabriel Costa, Edition 4, McGraw-Hill Education, 2014

BME-131_Human Physiology and Anatomy: (3+1)

The Cell and General Physiology. Functional organization of human body and control of the internal environment. Cell and its function, protein synthesis and cell reproduction. Metabolism of carbohydrates and formation of ATP. Lipid and Protein Metabolism, transport through Cell membrane. Human physiology from a system's view point, Nerve and Muscle, Sensory Systems, Somatic Sensations, Special Senses. Anatomy and its branches, Anatomical positions, planes, topography. Overview of Cellular Anatomy. Bones, muscles, ligaments, tendons, bursae, reticulae, capsules, arteries, veins, Lymphatic system. Vertebrae, Pelvic girdle, spinal cord, nervous system, Surface anatomy, bones surface musculature, lungs, heart, Organs (location, structures, relations and function), Bones, muscles, cranial nerves (location, structures, relations and function). Nervous System: Organization of Nervous System, Basic functions of synapses, Neuronal Mechanism and circuits for processing information. Motor Functions: Spinal cord and the cord reflexes; the cerebral cortex and intellectual functions of the Brain. Motor function of the Brain stem. Vestibular control of postural reflexes, Cerebrum and basal ganglia. Reticular formation. Behavioral functions of the Brain: Limbic System, role of the Hypothalamus, and control of the vegetative functions of the body; the Autonomic nervous system; the Adrenal Medulla. Electrical Activity from Brain. Endocrinology and Reproduction: Introduction to Endocrinology

Recommended Books:

- 1) A Text-Book of Medical Physiology by J E Hall, Edition 2, Elsevier, 2015.
- 2) Review of Medical Physiology by W. F. Boron, Edition 22nd, McGraw-Hill Companies, 2012.
- 3) Clinical Anatomy by for Medical Students by R Snell, Edition 8th, Lippincot Williams and Wilkins, 2000

Semester 3

BME-252_Modelling of Physiological Processes: (3+1)

Introduction, Basics of modeling and simulation, Examples and investigations of simulations in real system, Concept of modeling in Biomedical Engineering and realization of models in simulation systems. Definition of terminologies used in modeling and simulation, Discuss queuing theory (examples, why queues form and waiting lines), Describe components of a basic queuing process, Configuration of the service system, Digital simulation and mathematical modeling, Time-oriented and event-driven processes, A brief overview of the variety of mathematical models, Model of cardiorespiratory system (model requirements, conceptual model), Model of circulatory system (model requirements, conceptual and mathematical model), Model of respiratory system (model requirements, multiple/conceptual/mathematical models), Physiological control modeling (model requirements/conceptual/mathematical models), Applications of modeling of liver, heart and lungs.

Recommended Books:

- 1) Modeling and Simulation of Dynamic Systems by Robert L Woods, Edition 1st, Prentice Hall, 1997
- 2) Modeling Biomedical Signals by G Nardulli, Edition 1st, World Scientific Publishing Company, 2002
- 3) Modelling & Simulation in Biomedical Engineering by Willem Van Meurs, Edition 1st, McGraw Hill Education, 2011
- 4) Simulation Modeling and Analysis by A Law, Edition 5th, Publisher, 2014
- 5) Modelling and Simulation by L G Birta, Edition 2nd, Springer, 2013

BME-251_Biomaterials & Design: (3+1)

Biomaterials Science and Review: Hard Tissues and Pathologies, Orthopaedic prostheses, Properties of Natural Tissue Replacements. Biopolymers and Biomaterials: 3D structure of Biopolymers by Bio X-ray diffraction, Biomedical application of chitosan and other Biopolymers, Structure property relationships, Metals – Dental Implants, Bioceramics and Composites. Biocompatibility: Immune System, Corrosion, Deterioration of Non-metallic Materials, Mechanical Factors, Testing of Biomaterials. Applications: Joint Replacements, Fracture Fixation, Soft Tissue Implants, Vascular Implants, Tissue Engineering; Materials for Scaffolding.

Recommended Books:

- 1) Biomaterials Science, An introduction to Materials in Medicine by B D Ratner, Edition 3rd Academic Press, 2012
- 2) Introduction to Biomaterials by C M Agarwal, Edition 1st, Cambridge University Press, 2013
- 3) Biomaterials: An introduction by J Park, Edition 3rd, Springer, 2007.

HU-221_Technical Writing and Presentation Skills: (3+0)

This course has been designed to teach students to adapt their writing to different audiences and purposes. It will help learners develop strategies for making subjects clear to readers who need to understand them. Through this course, learners will learn to write in a clear, concise style and to present information logically, and to design documents in which format contributes to clarity and efficiency.

Recommended Books:

- 1) A Manual for Writers of Research Papers, Theses, and Dissertations: Chicago Style for Students and Researchers, by Kate L. Turabian, Wayne C. Booth, Gregory G. Colomb and Joseph M. Williams, Edition 8th, The University of Chicago Press, 2014
- 2) The Handbook of Technical Writing by Gerald J. Alred, Edition 11, Bedford/St. Martin's. 2015

BME-242_Biochemistry: (3+0)

Introduction to Biochemistry: pH, significance of pH Henderson equation, surface tension, viscosity, osmosis, diffusion, concept of chromatographic techniques (TLC, paper chromatography, GLC column chromatography etc.) carbohydrates, amino acids, nucleic acids, proteins, vitamins, enzymes, hormones & signaling agents. Metabolism of Carbohydrates, Lipids and Proteins: carbohydrate derivatives, optical activity, polarimetry, glycogenesis, gluconeogenesis, glycolysis, tricarboxylic acid cycle, hexose monophosphate shunt. Effects of hormones on carbohydrate.

Recommended Books:

- 1) Biochemistry by Richard A Harvey, Edition 5th, Lippincott Williams and Wilkins, 2010
- 2) Fundamentals of Biochemistry: Life at the Molecular Level by Donald Voet, Edition 4th, John Wiley and Sons, 2015

ME-100L_Workshop Practice: (0+1)

University Core. To be designed by the Department of Mechanical Engineering.

Recommended Books:

MA-234_Linear Algebra: (3+0)

The objective of the course is to introduce matrix theory and its underlying concepts with application to engineering problems. The topics covered include: matrices, Gaussian elimination, vector spaces, linear equations, orthogonality, determinants, eigenvalues, eigenvectors, similarity transformations, Jordan canonical form and singular value decomposition.

Recommended Books:

- 1) Linear Algebra and Its Applications by Gilbert Strang, Edition 4th, Cengage Learning, 2005.
- 2) Linear Algebra and Its Applications by David C. Lay, Edition 4th, Pearson, 2011.

Semester 4

BME-243_Cell and Molecular Biology: (3+1)

Introduction, Gene structure and organization, Central dogma of Molecular Biology, DNA Replication, Transcription and Translation. Transcription in prokaryotes and eukaryotes, DNA damage and repair, DNA Recombination and Transposition, Control of gene expression in prokaryotes and eukaryotes, Activators and repressors, chromatin and organization of DNA within cell, Molecular biology of mitochondria and chloroplasts, The Genetic Code, Codon & Anticodon Concept, Operon Concept. Mutagenesis & Mutations. Noncoding RNA.

Recommended Books

- 1) Molecular Biology of the Cell by Bruce Alberts, Edition 6th, Garland Science, 2014
- 2) Gene IX by Benjamin Lewin, Edition 9th, Jones and Bartlet Publishers, 2009
- 3) Chromatin and Gene Regulation by Brian M. Turner, Edition, Wiley Blackwell, 2008

MA-346_Numerical Methods: (3+0)

This course presents a broad overview of numerical methods for solving all the major problems in scientific computing, including linear and nonlinear equations, linear least squares, eigenvalue problems, optimization, interpolation, numerical integration and differentiation, initial and boundary value problems for ordinary differential equations, partial differential equations, fast Fourier transform and random numbers generators.

Recommended Books:

- 1) Numerical Analysis by Richard L. Burden, J. Douglas Faires, Annette M. Burden, Edition 1st, Brooks Cole, 2015
- 2) Applied Numerical Methods with MATLAB for Engineers and Scientists, by Stephen C. Chapra, Edition 3rd, McGraw Hill, 2011
- 3) An Introduction to Numerical Methods and Analysis, by James F. Epperson, Edition 2nd, John Wiley, 2013

EE-220_Signals and Systems: (3+0)

The objective of the course is twofold: (a) to provide the student with a solid mathematical foundation in complex variables and common engineering transforms and (b) to prepare the student for graduate-level core courses in communication, control and signal processing by giving the student a thorough working knowledge of these techniques. The topics covered include: analysis of linear time invariant systems, Fourier series, continuous and discrete time Fourier transform, Z-transform and Discrete Fourier Transform.

Recommended Books:

- 1) Signals and Systems, by Alan V. Oppenheim, Alan S. Willsky, and S. Hamid Nawab, Edition 2nd, Prentice Hall, 2008.
- 2) Schaum's Outline of Signals and Systems by Hwei Hsu, Edition 3, McGraw-Hill, 2013.

BME-211_Biophysics: (3+1)

Hearing and Echolocation, Ultrasound, Quantum Nature of Vision, Biophysics of Neural Spike. Information theory and Memory; Nervous system. Conformational analysis and forces that determine protein and nucleic acid structure. Molecular Modeling of protein, nucleic-acid structures. Interaction of radiation with matter, Biological effects of radiation, radiobiological effects of radiation, medical imaging using radio-isotopes. Electrocardiograms and electric shocks, Fundamental laws for current in biological tissues, Biopotentials in hearts, electrocardiogram, Action potentials in nervous system. Thermodynamic principles. First law (energy, enthalpy), Second law of Thermodynamics. Free energy, standard physical free energy and standard biological free energy, determination of the free energy from equilibrium constant and EMF measurements. Thermodynamics of phosphate compounds (phosphate transfer reactions) and role of ATP for biological energy transfer, thermodynamics of life. Coupled Reactions, Group Transfer Potential, Role of Pyridine Nucleotides, Energy Conversion Pathways, Biological Membrane, Active Transport, Chemi-osmotic theory-passive transport.

Recommended Books:

- 1) Biophysics: An Introduction by Roland Glaser, Edition 2nd, Springer, 2012
- 2) Biological Physics by Philip Nelson, Edition 1, W H Freeman, 2013
- 3) Fundamentals of Biophysics by A B Rubin, Edition 1st, Wiley, 2014

EE-272_Digital Systems: (3+1)

The topics covered include: Combinational Logic Design, simplification of Boolean expressions, Sequential Logic Design, Logic design with Hardware Description Languages such as Verilog, Digital Building Blocks, Architecture, Microarchitecture, Memory Systems, I/O Systems, Digital System Implementation.

Recommended Books:

- 1) Digital Design and Computer Architecture by Sarah Harris, David Harris, Edition 2, Morgan Kaufmann, 2015
- 2) Logic and Computer Design Fundamentals, by M. Morris Mano, Charles R. Kime, Tom Martin, Edition 5th, Prentice-hall, 2015
- 3) Digital Design: With an Introduction to the Verilog HDL, by M. Morris Mano and Michael D. Ciletti, Edition 5th Prentice Hall, 2012
- 4) Digital Systems: Principles and Applications by Ronald J. Tocci, Neal Widmer and Greg Moss, Edition 11th, Pearson, 2010

Semester 5

IS-101_Islamic/Ethics & Pakistan Studies-I: (3+0)

University Core. To be designed by the Department of Islamic Studies

Recommended Books:

BME-312_Biomechanics: (3+1)

Statics: General principles of Statics, laws of triangle, Parallelogram and polygon forces, Equilibrium of rigid body, Free body Diagrams. Trusses, Methods of Joints and section for force analysis. Shear force and bending moments. Application of these forces with analysis in human body. Dynamics: Rectilinear and curvilinear motion, Rotational mechanics, Simple and multiple degrees of freedom, Application of these motions in human body and prosthetics. Fluid Mechanics: Basic concepts of Fluid Mechanics, Hydrodynamic lubrication of natural and normal synovial joints. Biomedical Applications: Mechanical properties of biological tissues and tissue mechanics, cardiac mechanics and modeling, muscle mechanics, gait kinetics, kinematics and analysis. Stress analysis and application to musculoskeletal system.

Recommended Books:

- 1) Basic Bio-Mechanics by Susan J. Hall, Edition 7th, McGraw Hill Education, 2014.
- 2) Bio-Mechanics Principles and Application by Donald R Peterson, Edition 2nd, CRC Press, 2007
- 3) Biomechanics and Motor Control: Defining Central Concepts by M L Latash, Edition 1st, Academic Press, 2015

EE-302_Applied Probability (3+0)

(Pre-Requisite: Signals and Systems and Linear Algebra)

The course introduces students to the modeling, quantification, and analysis of uncertainty. Topics covered include: formulation and solution in sample space, the concept of random variables (both discrete and continuous), simple random processes and their probability distributions, conditional probability, independence and conditional independence, transform techniques, use of moment generating functions for evaluating probability distributions, functions of one and many random variables, the concept of derived distributions involving

convolution, Markov processes, limit theorems, and elements of statistical inference based on maximum-a-posteriori-probability as well as maximum likelihood.

Recommended Books:

- 1) Introduction to Probability, by Dimitri P. Bertsekas, John N. Tsitsiklis, 2nd Edition, Athena Scientific, 2008
- 2) Probability, Random Variables and Stochastic Processes, by Athanasios Papoulis and S. Unnikrishna Pillai, Edition 4th, McGraw Hill, 2002

EE-273_Microprocessor Systems: (3+1)

The course covers: Microprocessor systems, bus structure, DMA and interrupts, microprocessor architecture, memory and I/O ports, addressing modes, instruction set, microprocessor programming techniques, Microcontrollers, Memory system design, CPU read/write timing, RAM and ROM interface requirements, address decoding and interfacing dynamic RAM, Interfacing, serial, parallel, programmed and interrupt driven I/O, direct memory access and peripheral controllers, programmable peripheral interface, universal synchronous/asynchronous receiver/transmitter, programmable interrupt controller and data communication standards.

Recommended Books:

- 1) Embedded Systems: Introduction to Arm Cortex-M Microcontrollers, by Jonathan W. Valvano, Edition 5th, CreateSpace Independent Publishing Platform, 2012
- 2) Embedded Systems: Real-Time Interfacing to Arm® Cortex™-M Microcontrollers, by Jonathan W. Valvano, Edition 2nd, Create Space Independent Publishing Platform, 2011

BME-332_Biomedical Instrumentation: (3+1)

Introduction: Precision, resolution, sensitivity, accuracy, uncertainty, Principles & development of Biomedical Instrumentation, Problems encountered in living systems. Biological Systems: Study of various Physiological systems, related biopotentials and physiological parameters. Diagnostic Equipment: invasive and noninvasive measurement techniques and related equipment. Cardiovascular Measurements: Electrocardiography, Measurement of Blood pressure, Blood flow and Cardiac output. Biomedical Sensors & Transducers: Introduction, principles, theory, design and applications, Principles and design, Speed, Position, Temperature, light & Pressure transducers, Programmable logic controller, PLC interfacing, memory processor. Patient Monitoring Equipment: Patient Monitors, central monitoring system, telemetry system, Gas Exchange and distributions, Respiratory therapy equipment. Therapeutic Equipment: ventilator, inhaler, defibrillator, pacemaker and heart lung machines. Radiological Equipment: concept of ionization and nonionization radiation and related equipment, medical lasers and applications. Safety in Medical Equipment: Electrical/Mechanical safety, Standards of Medical Devices, Biohazards and Safety Regulations. Quality Assurance and Quality Control: Calibration, maintenance and reparability of monitoring equipment.

Recommended Books:

- 1) Biomedical Instrumentation System by Shakti Chatterjee, Edition 1st, Cengage, 2010
- 2) Biomedical Instrumentation: Technology and Applications by R Khandpur, Edition 1st, McGraw Hill Education, 2004
- 3) Medical Instrumentation: Application and Design by J G Webster, Edition 4th, Wiley India Private Limited, 2009

Semester 6

BME-321-Biomedical Signal Processing: (3+1)

Review of signals and systems and their properties, Modeling of Dynamic Systems, Linear Constant Coefficients Differential Equation (LCCDE) and Difference Equation, Review of Laplace transform, Transfer Function, Poles and Zeros, Sampling and Reconstruction, up-sampling and down sampling, Z-transform and its application in the analysis of Discrete LTI system, computation of frequency response from Pole, Zero plot, Review of the Frequency domain analysis of Continuous time systems, CTFS, CTFT, DTFT, DFT (DTFS), FFT, Design and implementation of analog and digital finite impulse response (FIR) and infinite impulse response (IIR) filters. A quick introduction to statistical signal processing, feature extraction and pattern recognition techniques, Case Studies of various Biomedical Signals: ECG, EEG.

Recommended Books:

- 1) Signals & Systems in Biomedical Engineering: Signal processing and physiological systems modeling by S R Devasahayam, Edition 2nd, Springer, 2012
- 2) Biomedical Signal Processing and Signal Modeling by Engene, N, Bruce, Edition 1, John Wiley & Sons, 2001.
- 3) Biosignal and Medical Image Processing by J L Semmlow, Edition 3rd, CRC Press, 2014
- 4) Biomedical Signal Analysis by R M Rangayyan, Edition 2nd, Wiley, 2015

BME-333_Clinical Laboratory Instrumentation: (3+1)

Microscopy: Electron Microscopy, Atomic Force Microscopy, Confocal Microscopy. Spectroscopy: U. V., I. R., NMR & Visible Absorption, Fluorometric Methods, Flame Photometry, Spectrographic Spectroscopy, Circular Dichroism, Mass Spectrometry. Electrochemical methods of analysis: Electrophoresis Chromatography, High Performance Liquid Chromatography, Clinical Chemistry Analysis, Study of different blood components through automated cell-counter, Centrifuging Techniques, Blood Banking and Transfusion, Service Automation, Polymerase Chain Reaction.

Recommended Books:

- 1) Medical Instrumentation: Application and Design by John G. Webster, Edition 4th, John Wiley & Sons Inc, 2009.

- 2) Biomedical Instrumentation System by Shakti Chatterjee, Edition 1st, Cengage Learning, 2010
- 3) Biomedical Instrumentation: Technology and Applications by R Khandpur, Edition 1st, McGraw Hill, 2004

IS-201_Islamic/Ethics and Pakistan Studies-II: (3+0)

University Core. To be designed by the Department of Islamic Studies

Recommended Books:

EE-380_Electromagnetic Theory: (3+0)

This course gives the transition from temporal lumped to spatial-temporal distributed circuitry and provides a solid background of a firm understanding of Maxwell equations and their experimental basis finally culminating in the most important manifestation of Maxwell equations: the space-time varying Electromagnetic waves. The contents to be covered include: Cylindrical and spherical coordinate systems, Conversion between different coordinate systems, Lumped versus distributed electrical circuits, transient response of transmission line, Steady-state waves on transmission line, Electric charge, Coulomb's Law, Electric field, Electric potential, Electric flux and Gauss's law, Divergence: differential form of Gauss's law, Metallic conductors, Poisson's and Laplace's equations, Capacitance, Dielectric materials, Electrostatic Boundary conditions, Electrostatic energy, Current density and Microscopic view of conduction, Current flow, ohm law and resistance, EMF and Kirchhoff's voltage law, Continuity equation and Kirchhoff's current law, Boundary Conditions for steady current flow, Duality of J and D; Resistance capacitance analogy, Joule's law Ampere's law of force, Biot-Savart Law & Applications, Ampere's circuital law, Curl of the magnetic field, Differential form of Ampere's law, Vector Magnetic Potential, Divergence of B, Magnetic Flux and Inductance, Magnetic fields in material media, Boundary conditions for magneto static fields, Faraday's Law, Induction due to motion, Energy in a magnetic field, Displacement Current and Maxwell's Equations and Plane electromagnetic waves in an unbounded medium.

Recommended Books:

- 1) Engineering Electromagnetics and Waves, by Umran S. Inan, Aziz S. Inan, Edition 2nd, Prentice Hall, 2014
- 2) Engineering Electromagnetics, by William Hayt and John Buck, Edition 8th, McGraw Hill, 2011

BME-352_Tissue Engineering: (3+1)

Tissue Engineering, Fundamentals of Tissue Engineering, The extracellular matrix (ECM) Collagen Elastin, Proteoglycans and glycosaminoglycans, Basics of Cell Biology, Sources (autograft, allograft, xenograft, stem cell), selection and potential manipulation, Biocompatibility (Immunosuppression, Immunoisolation, Genetic engineering) and the foreign body reaction, Biomaterials used in tissue engineering, Synthetic, Inorganic, Naturally-derived, Scaffolds for tissue engineering, Tissue engineering of skin, tendons and ligaments, Tissue engineering of blood vessels and heart valves, Tissue engineering of cartilage and bone, Tissue

engineering of nerve regeneration and organ replacement, Tissue engineering of cornea, Ethical and regulatory issues in tissue engineering

Recommended Books:

- 1) Tissue Engineering by C. V. Blitterswijk, Edition 2nd, Academic Press, 2014
- 2) Principles of Tissue Engineering by R. Lanza, Edition 4th, Academic Press, 2014

Semester 7

MGT-4XX_Management Elective: (3+0)

Out of BME-413, BME-414, BME-415 & BME-416 one course would be offered as Elective 1(BME-4XX)

BME-413_Rehabilitation Engineering and Sports medicine: (2+1)

Overview, Design and Prescription of prosthetic limbs, orthotic, seating & positioning systems. Introduction to injuries, disability, human movement, kinesiology. Biomechanics, Gait analysis, prosthetics, orthotics and mobility assist technology. Improvement of performance and prevention of injuries. Prosthetic and orthotic design and usage, visual and hearing impairment. Design tools and principles of universal design, and various technology-transfer mechanisms, models, and principles. Design and service delivery principles of wheelchairs and scooters, functional electrical stimulation and its applications, wheelchair-accessible transportation legislation, and the applications of robotics in medical rehabilitation. Introduction to sports medicine, Body organizations and tissue response to injury. Injuries to foot, ankle, hip, shoulder, knee and upper limbs. Internal injuries and nutritional considerations. First-aid, CPR and emergency response.

Recommended books:

- 1) An introduction to rehabilitation engineering (Series in Medical Physics and Biomedical Engineering) by Rory A Cooper, Hisaichi Ohnabe. Edition 1, CRC Press, 2006
- 2) Physical Rehabilitation by Susan B Osullivan, Edition 6th, F A Davis, 2013
- 3) The sports medicine patient advisor by P. A. Rouzier, Edition 3rd, Sports Med Press, 2010

BME-414_Biomedical Robotics: (2+1)

Introduction to medical robotics, kinematics of medical robots, Teleportation and cooperative manipulation. Robot dynamics and simulation. Trajectory generation, Surgeon's perspective. Medical imaging and image-guided interventions. Tracking and surgical navigation. Motion planning, prediction, correlation, replication and learning. Basic methods behind robots like

DaVinci system, the cyberknife, motorized C-arms and operating microscopes as well as strategic frames. Broad spectrum of medical and healthcare robotics. Robots for neuroscience.

Recommended Books:

- 1) Medical Robotics by Achim Schweikard and Floris Ernst, Edition 1st, Springer, 2015
- 2) Medical Robotics by Jocelyne Troccaz, Edition 1st, Wiley-ISTE, 2012

BME-415_Biofluid Mechanics: (2+1)

Basic concepts in fluid mechanics: Viscosity, surface tension, compressibility; hydrostatics, pressure on plate; kinetics & kinematics of fluid flow; continuity equation; conservation of momentum; Bernoulli's equation; Poiseuille equation; viscous, unsteady flows; dimensional analysis. Physiological Fluid Mechanics: Introduction to blood flow in the circulatory system, respiration, peristaltic motion, ciliary and flagellar transport, Rheology of blood and blood vessels, static and steady flow model, native heart valve, Fluid dynamics measurement techniques.

Recommended Books:

- 1) Biofluid Mechanics by David Rubenstein, Edition 2nd, Academic Press, 2015
- 2) Biofluid Mechanics: The human circulation by Krishnan B. Chandran, Edition 2nd, CRC Press, 2012

EE-340_Control Systems: (3+1)

Modeling of Physical Systems: Importance of modeling. Formation of differential equations of electrical, mechanical, electromechanical and other systems. Transient Response: Poles and zeros of a transfer function, stability, standardized inputs, steady – state and transient response of first – order, second order and higher order systems. Transient response specifications in time and frequency domain. State-Space Representation and Analysis: Introduction to state space concepts and terminology, formation of state and output equations for physical systems. Solution of state equations, Eigenvalues and Eigen vectors, state – transition and transfer function matrices. Steady-State Response: Types and analysis of feedback control systems based on steady-state error coefficients, sensitivity function. Time Domain Analysis: Root locus diagrams, Analysis and Design of Control Systems Based on Root locus technique. Frequency Domain Analysis: Routh-Herwitz Stability criterion, Bode plots, Polar plots, Nyquist stability criterion, Gain and phase margins, Nichol's chart.

Recommended Books:

- 1) Control System Engineering by Norman S. Nise, Edition 7th, Wiley, 2015
- 2) Physiological control systems by Micheal C. Khoo, Edition 1st, Wiley-IEEE Press, 1999
- 3) Schaum's outline of feedback and control systems by J Distefano, Edition 2nd, McGraw Hill Education, 2013

IME-251_Social and Ethical Aspects in Engineering: (2+0)

The course covers: Ethics and various ethical theories, accepting and sharing responsibilities, ethical dilemmas and making moral choices, importance, limitations, abuse and justification of codes, utilitarianism, right, duty and virtue ethics, socially conscious engineering, engineering, ecology and economics, ethical frameworks, safety and risk, assessing and reducing risk, team work, confidentiality, and conflict of interest, trustfulness and trustworthiness, expert witness and advisors, research integrity, technology transfer, computer ethics and Internet.

Recommended Books:

- 1) Ethics in Engineering, by Mike W. Martin, Edition 4th, McGraw-Hill Education, 2004.
- 2) Engineering Ethics: Concepts and Cases by Charles E. Harris Jr., Michael S. Pritchard, Michael J. Rabins, Ray James and Elaine Englehardt, Edition 5th, Cengage Learning, 2013
- 3) Engineering Ethics by Charles B, Edition 4th, Fleddermann, Pearson, 2011

BME-499a_Project (Phase-I): (0+3)

The goal of this course is to give the students a chance to showcase their technical capabilities by applying their theoretical and practical knowledge in the field of R&D.

Semester 8

Out of BME-423, BME-424 & BME-444 two Electives (Elective 2 (BME-4YY) and Elective 3 (BME-4ZZ) would be offered.

BME- 423_Telemedicine and Medical Informatics: (2+1)

Introduction to Telemedicine and Telehealth, Practical examples/ Case Studies. Telehealth in Home, Smart Housing and Communities, Telemedicine for health professionals. Telehealth in developing world. Human and sociotechnical factors. Ethical and legal Challenges. Evaluation and future trends in Telemedical systems. What is medical informatics? DICOM: its significance and working. Basic medical imaging: acquisition, diagnostic, enhance and analysis. Advanced Medical Imaging. Networking medical data: clouds, web. Introduction to Teleradiology, Scaling of clinical projects. Security and confidentiality in medicine. Fault-tolerance and robustness. Clinical modeling and performance optimization. Complex clinical data: from visualization to data-mining. HL7, IHE and workflow integration.

Recommended Books:

- 1) Telemedicine and Telehealth 2.0: A practical guide for medical providers and patients by V. Lyuboslavsky, Edition 1st, CreateSpace Independent Publishing Platform, 2015
- 2) Telemedicine technologies: Information technologies in medicine and telehealth by B. Fong, Edition 1st, Wiley, 2010.
- 3) Biomedical Informatics: Computer applications in health care and biomedicine by E. H. Shortliffe, Edition 4th, Springer, 2014

BME-424_Neuroscience & Neural Networks: (2+1)

Introduction to neuroscience: nervous system, sympathetic, parasympathetic and motor nervous system and their functions, brain and its functions. Neurons and glia, structure of a neuronal cell, types of glia, blood brain barriers. Signaling in the brain: electrical excitability of neurons, resting membrane potential, action potential, intra neuronal signaling, inter neuronal signaling. Synaptic events, chemical messengers, synaptic transmission. Receptors: Ionotropic and metabotropic receptors, signal transduction pathways, G-proteins, protein phosphorylation. Signaling to the nucleus, regulation of gene expression. Neurotransmitters: Excitatory and inhibitory amino acid neurotransmitters and functions in the brain, role of excitatory neurotransmitter in learning and memory. Diseases associated with the malfunctioning of these neurotransmitters. Catecholamines: functions in the brain, Diseases associated with the malfunctioning. Artificial Neural Network: Model of single neuron, neural network architectures. Feed forward neural networks. Multilayer perception, back propagation algorithm, radial basis function networks. Unsupervised learning. Hopfield network, self organizing map, other unsupervised networks. Reinforcement learning.

Recommended Books:

- 1) Neural Networks and Learning Machines by S. Haykin, Edition 3, Pearson., 2008
- 2) Theoretical Neuroscience: computational and mathematical modeling of neural system by Peter Dayan, Edition 1, MIT Prsa, 2005
- 3) Neural Network Design by M T Hagan, Edition 2nd, Martin Hagan, 2014
- 4) Neural Networks by R Shankar, Edition 1st, Independently Published, 2016

BME-444_Genetic Engineering: (2+1)

Introduction, History, The advent and importance of gene cloning and the polymerase chain reaction, Vectors for Gene Cloning, Purification of DNA from Living Cells, Manipulation of Purified DNA, Introduction of DNA into Living Cells. Cloning Vectors for E. coli, λ and other high capacity vectors, Cloning Vectors for Eukaryotes, Genomics & cDNA Libraries. Polymerase Chain Reaction & qPCR, Electrophoresis & Blotting Techniques, Site- Directed Mutagenesis, DNA Sequencing, Reporter Gene Assays, DNA-Protein Interaction Assays, Protein-Protein Interaction Assays, DNA Fingerprinting. Gene Transfer Methods, Kock-out, Knock-in & RNA interference, Transgenic.

Recommended Books:

- 1) Introduction to Genetic Analysis by Anthony JF Griffith, Edition 11th, W H Freeman, 2015
- 2) Principles of Gene Manipulation & Genomics by Sandy B. Primrose, Richard Twyman, Edition 8th, Blackwell, 2016
- 3) Gene Cloning and DNA Analysis: An Introduction by T. A. Brown, Edition 7th, Wiley Blackwell, 2016

BME-422_Biomedical Imaging: (3+1)

Introduction: Interaction of Radiation with Matter, Scattered & absorbed Radiation, spatial image formation. Imaging Transducers: Various transducers used in medical imaging systems. Imaging development: X-ray Film, Fluoroscopic imaging, Digital Imaging System, X-ray imaging, Film-less radiographic imaging, CT imaging, Emission Tomography imaging,

Nuclear imaging, MR Imaging, Functional MRI imaging, Advance imaging modalities like PET and SPECT. Emerging areas in medical imaging. Ultrasound Imaging: Ultrasonic imaging, Doppler Imaging, software based estimations and measurement in ultrasonic imaging. Planar and Volumetric analysis techniques. Medical imaging software: Algorithms, techniques, imaging archival and management. Molecular imaging and other advance biomedical imaging techniques and their image manipulation. Quality Assurance and Control in Medical Imaging Equipment: Quality assurance of medical imaging, Evaluation of imaging parameter and related equipment calibration, Diagnostic values, Statistical performance measures.

Recommended Books:

1. Medical Imaging Signals and Systems by Jerry L Prince, Edition 2nd, Pearson, 2014
2. Introduction to Medical Imaging by N B Smith, Edition 1st, Cambridge University Press, 2010
3. The Essential Physics of Medical Imaging by Bushberg J.T., Edition 2nd, LWW, 2011
4. Fundamental Mathematics and Physics of Medical Imaging by J Lancaster, Edition 1st, CRC Press, 2016

***HU-4XX* _Clinical Psychology: (2+0)**

Introduction to clinical psychology and evolution of clinical psychology. An insight into contemporary clinical psychology. How do we diagnose mental illness? The central importance of research in clinical psychology. Assessment methodology, Interview/observational assessment methods. Intellectual and cognitive measure of assessment. Self-report and projective measures of assessment. Integration and clinical decision-making. Overview of Intervention, Intervention in adults and couples. Intervention in children and adolescents. Identification of key elements of change. Health/Neuropsychology/Forensic. Career planning for clinical psychology.

Recommended Books:

- 1) Introduction to Clinical Psychology by G. P. Kramer, Edition 8th, Pearson, 2013.
- 2) Clinical Psychology by T. J. Trull, Edition 8th, Wadsworth Publishing, 2012

***BME-499b* _Project (Phase-I): (0+3)**

The goal of this course is to give the students a chance to showcase their technical capabilities by applying their theoretical and practical knowledge in the field of R&D.