# Biomedical Engineering Centre

*UET Lahore (KSK Campus)*

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

*Revised (September 2019)*

**FRAMEWORK/TEMPLATE FOR**
**BE/BS IN BIOMEDICAL ENGINEERING as per HEC**

| | |
|---|---|
| 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: | **134** |
| Number of credit hours per semester: | 14-18 |
| Engineering Courses (Minimum): | **71%** |
| Non-Engineering Courses (Maximum): | **29%** |

Designed and improved by faculty of Biomedical Engineering Centre (KSK and Narowal Campus)

| Non-Engineering Domain | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Knowledge Area** | **Subject Area** | **Name of Course** | **Lec CH** | **Lab CH** | **Total CH** | **Total Courses** | **Total Credits** | **% Area** | **% Overall** |
| Humanities | English | Communication Skills (HU-111L) | 0 | 1 | 1 | 2 | 4 | 10.25 | 2.9 |
| | | Technical Writing & Presentation Skills (HU-221) | 3 | 0 | 3 | | | | |
| | Culture | Islamic & Pak Studies 1 (IS-101) | 3 | 0 | 3 | 2 | 6 | 15.38 | 4.4 |
| | | Islamic & Pak Studies 2 (IS-201) | 3 | 0 | 3 | | | | |
| | Social Science | Social & Ethical Aspects in Engineering (IME-251) | 2 | 0 | 2 | 1 | 2 | 5.1 | 1.4 |
| Management | | Management Elective 1 (MGT-XXX) | 3 | 0 | 3 | 2 | 6 | 15.38 | 4.4 |
| | | Management Elective 2 (MGT-XXX) | 3 | 0 | 3 | | | | |
| Natural Sciences | Physics | Applied Physics (PHY-111) | 2 | 1 | 3 | 1 | 3 | 7.6 | 2.2 |
| | Mathem | Calculus & Analytical Geometry | 3 | 0 | 3 | 4 | 12 | 30.76 | 8.9 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | atics | (MA-113) | | | | | | | |
| | | Linear Algebra & Differential Equations (MA-116) | 3 | 0 | 3 | | | | |
| | | Numerical Methods (MA-346) | 3 | 0 | 3 | | | | |
| | | Complex Variable & Transformation (MA-221) | 3 | 0 | 3 | | | | |
| | Core | | | | | 2 | 6 | 15.38 | 4.4 |
| | | Biochemistry (BME-214) | 2 | 1 | 3 | | | | |
| | | Basic Math/Basic Biology (MA-110/BME-104) | 3,2 | 0,1 | 3 | | | | |
| **Total** | | | | | | **14** | **39** | **100** | **29.10** |

| **Engineering Domain** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Knowledge Area** | **Subject Area** | **Name of Course** | **Lec CH** | **Lab CH** | **Total CH** | **Total Courses** | **Total Credits** | **% Area** | **% Overall** |
| Computing | Fundamentals | Introduction to Computing (CS-141) | 3 | 1 | 4 | 3 | 11 | 11.57 | 8.2 |
| | | Programming Fundamentals (CS-142) | 3 | 1 | 4 | | | | |
| | Design | Biomedical Modeling and Simulation (BME-244) | 2 | 1 | 3 | | | | |
| Biomedical Engineering | | Basic Electrical & Electronics | 3 | 1 | 4 | 11 | 31 | 32.63 | 23.13 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Foundation<br><br>(Core) | | Engineering (EE-199) | | | | | | | |
| | | Physiology 1 (BME-102) | 2 | 1 | 3 | | | | |
| | | Human Anatomy (BME-103) | 2 | 1 | 3 | | | | |
| | | Introduction to Biomedical Engineering (BME-101) | 1 | 0 | 1 | | | | |
| | | Physiology 2 (BME-201) | 2 | 1 | 3 | | | | |
| | | Digital Logic Design<br><br>(CSE-221) | 3 | 1 | 4 | | | | |
| | | Circuit Analysis<br><br>(EE-110) | 3 | 1 | 4 | | | | |
| | | Semiconductor Devices (EE-212) | 3 | 1 | 4 | | | | |
| | | Engineering Drawing (ME-124L) | 0 | 1 | 1 | | | | |
| | | Workshop Practice (ME-100L) | 0 | 1 | 1 | | | | |
| | | Cellular & Molecular Biology (BME-202) | 2 | 1 | 3 | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Major Based Core (Breadth) | | Applied Probability & Statistics (EE-320) | 3 | 0 | 3 | 5 | 16 | 16.84 | 11.94 |
| | | Biomedical Electronics (BME-213) | 2 | 1 | 3 | | | | |
| | | Biomedical Instrumentation 1 (BME-310) | 2 | 1 | 3 | | | | |
| | | Signals & Systems (EE-220) | 3 | 0 | 3 | | | | |
| | | Microprocessor Systems ( EE-273) | 3 | 1 | 4 | | | | |
| Major Based Core (Depth) | | Biomechanics (BME-212) | 2 | 1 | 3 | 5 | 16 | 16.84 | 11.94 |
| | | Control Systems (EE-340) | 3 | 1 | 4 | | | | |
| | | Biomedical Instrumentation 2 (BME-318) | 2 | 1 | 3 | | | | |
| | | Biomaterials (BME-313) | 2 | 1 | 3 | | | | |
| | | Medical Imaging (BME-411) | 2 | 1 | 3 | | | | |
| Interdisciplinary Engineering Breadth (Electives) | | Elective 1 (BME-XXX) | 3 | 0 | 3 | 5 | 15 | 15.78 | 11.19 |
| | | Elective 2 | 3 | 0 | 3 | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | (BME-XXX) | | | | | | | |
| | | Elective 3 (BME-XXX) | 3 | 0 | 3 | | | | |
| | | Elective 4 (BME-XXX) | 3 | 0 | 3 | | | | |
| | | Elective 5 (BME-XXX) | 3 | 0 | 3 | | | | |
| Senior Design Project | | Biomedical Engineering Project (BME-412a & b) | 0 | 6 | 6 | 2 | 6 | 6.3 | 4.4 |
| **Total** | | | | | | **31** | **95** | **100** | **70.9** |

| **Summary** | | | | |
|---|---|---|---|---|
| **Domain** | **Knowledge Area** | **Total Courses** | **Total Credits** | **% Overall** |
| Non-Engineering | Humanities | 5 | 12 | **29.10** |
| | Management Sciences | 2 | 6 | |
| | Natural Sciences | 7 | 21 | |
| | **Sub Total** | **14** | **39** | |
| Engineering | Computing | 3 | 11 | |
| | Biomedical Engineering Foundation (Core) | 11 | 31 | **70.90** |
| | Major Based Core (Breadth) | 5 | 16 | |
| | Major Based Core (Depth) | 5 | 16 | |
| | Interdisciplinary Technical Electives | 5 | 15 | |
| | Senior Year Project | 2 | 6 | |
| | **Sub Total** | **31** | **95** | |
| **Grand Total** | | **45** | **134** | **100** |

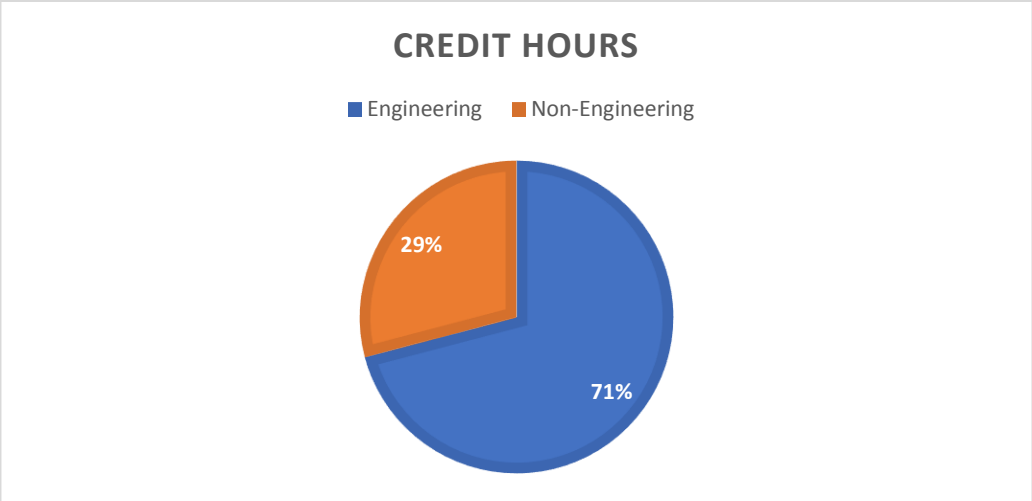
# Scheme of Studies for BE/BS (4 Years) in Biomedical Engineering

| First Semester | | | | Second Semester | | | |
|---|---|---|---|---|---|---|---|
| Applied Physics (PHY-111) | 2 | 1 | 3 | Human Anatomy (BME-103) | 2 | 1 | 3 |
| Introduction to Computing (CS-141) | 3 | 1 | 4 | Calculus & Analytical Geometry (MA-113) | 3 | 0 | 3 |
| Basic Electrical & Electronics Engineering (EE-199) | 3 | 1 | 4 | Physiology 1 (BME-102) | 2 | 1 | 3 |
| Basic Biology (BME-104)/Basic Mathematics (MA-110) | 2,3 | 1,0 | 3 | Circuit Analysis (EE-110) | 3 | 1 | 4 |
| International Language | 0 | 0 | 0 | Programming Fundamentals (CS-142) | 3 | 1 | 4 |
| Introduction of Biomedical Engineering (BME-101) | 1 | 0 | 1 | Engineering Drawing (ME-124L) | 0 | 1 | 1 |
| Islamic & Pak Studies 1 (IS-101) | 3 | 0 | 3 | | | | |
| **Total** | **14/15** | **4/3** | **18** | **Total** | **13** | **5** | **18** |

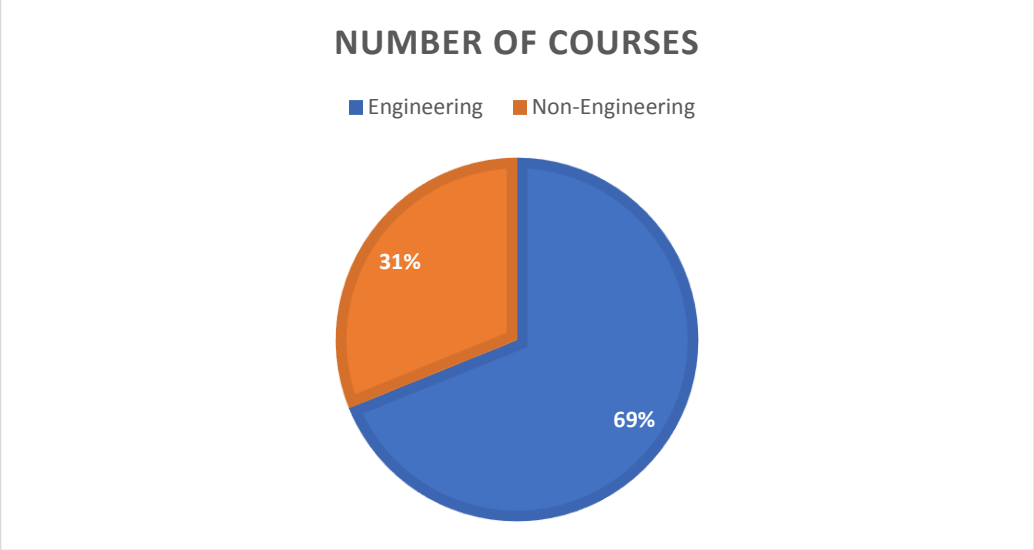
| Third Semester | | | | Fourth Semester | | | |
|---|---|---|---|---|---|---|---|
| Linear Algebra & Differential Equations (MA-116) | 3 | 0 | 3 | Biomedical Electronics (BME-213) | 2 | 1 | 3 |
| Physiology 2 (BME-201) | 2 | 1 | 3 | Digital Logic Design (CSE-221) | 3 | 1 | 4 |
| Biochemistry (BME-214) | 2 | 1 | 3 | Complex Variable & Transform (MA-221) | 3 | 0 | 3 |
| Semiconductor Devices (EE-212) | 3 | 1 | 4 | Cellular & Molecular Biology (BME-202) | 2 | 1 | 3 |
| Workshop Practice (ME-100L) | 0 | 1 | 1 | Signals & Systems (EE-220) | 3 | 0 | 3 |
| Communication Skills (HU-111L) | 0 | 1 | 1 | | | | |
| Islamic & Pak Studies 2 (IS-201) | 3 | 0 | 3 | | | | |
| **Total** | **13** | **5** | **18** | **Total** | **13** | **3** | **16** |

| Fifth Semester | | | | Sixth Semester | | | |
|---|---|---|---|---|---|---|---|
| Biomedical Instrumentation 1 (BME-310) | 2 | 1 | 3 | Biomedical Instrumentation 2 (BME-318) | 2 | 1 | 3 |
| Applied Probability & Statistics (EE-320) | 3 | 0 | 3 | Technical Elective 1 (BME-XXX) | 3 | 0 | 3 |
| Numerical Methods (MA-346) | 3 | 0 | 3 | Control Systems (EE-340) | 3 | 1 | 4 |
| Microprocessor Systems (EE-273) | 3 | 1 | 4 | Biomedical Modeling & Simulation (BME-244) | 2 | 1 | 3 |
| Biomaterials (BME-313) | 2 | 1 | 3 | Biomechanics (BME-212) | 2 | 1 | 3 |
| | | | | | | | |
| | | | | | | | |
| **Total** | **13** | **3** | **16** | **Total** | **12** | **4** | **16** |

| Seventh Semester | | | | Eighth Semester | | | |
|---|---|---|---|---|---|---|---|
| Management Elective 1 (MGT-XXX) | 3 | 0 | 3 | Technical Elective 4 (BME-XXX) | 3 | 0 | 3 |
| Medical Imaging (BME-411) | 2 | 1 | 3 | Social & Ethical Aspects in Engineering (IME-251) | 2 | 0 | 2 |
| Technical Elective 2 (BME-XXX) | 3 | 0 | 3 | Technical Elective 5 (BME-XXX) | 3 | 0 | 3 |
| Technical Elective 3 (BME-XXX) | 3 | 0 | 3 | Management Elective 2 (MGT-XXX) | 3 | 0 | 3 |
| Technical Writing & Presentation Skills (HU-221) | 3 | 0 | 3 | Biomedical Engineering Project Phase 2 (BME-412b) | 0 | 3 | 3 |
| Biomedical Engineering Project Phase 1 (BME-412a) | 0 | 3 | 3 | | | | |
| | | | | | | | |
| **Total** | **14** | **4** | **18** | **Total** | **11** | **3** | **14** |




**Engineering/Non-Engineering ratio**




**Engineering/Non-Engineering ratio**

**List of Technical Electives: (5 out of given 23 must be chosen)**

1. BME-314 Bioelectricity (3+0)
2. EE-392 Power Electronics (2+1)
3. BME-433 Rehabilitation and Sports Medicine (2+1)
4. BME-414 Biomedical Robotics (2+1)
5. BME-415 Biofluid Mechanics (2+1)
6. BME-416 Bioinformatics (3+0)
7. CS-361 Artificial Intelligence (3+1)
8. BME-418 Hospital Information Management Systems (3+0)
9. BME-419 Medical Device Quality Systems and Standards (3+0)
10. BME-420 Medical Image Processing (2+1)
11. BME-423 Telemedicine Systems (2+1)
12. BME-421 Biophysics (2+1)
13. BME-425 DNA Computing (3+0)
14. BME-316 Drug Delivery Systems (3+0)
15. BME-444 Genetic Engineering (3+0)
16. BME-432 Neuroscience & Neural Networks (3+0)
17. BME-426 Regenerative Medicine (3+0)
18. BME-427 Tissue Engineering (3+0)
19. BME-317 Computational Fluid Dynamics (3+0)
20. BME-428 Nano-Biotechnology (3+0)
21. BME-429 Medical Device Regulatory Affairs (3+0)
22. EE-439 Introduction to Machine Learning (3+0)
23. BME-311 Biomedical Signal Processing (2+1)

**List of Management Electives: (2 out of given 6 must be chosen)**

1. MGT 211: Principles of Management (3+0)
2. MGT 310: Production and Operations Management (3+0)
3. MGT 313: Total Quality Management (3+0)
4. MGT 410: Project Management (3+0)
5. MGT 414: Entrepreneurship and Business Management (3+0)
6. MGT 460: Engineering Economics (3+0)

## Semester 1

*PHY-111_* **Applied Physics: (2+1)**

*Course Outline:*

The objective of this course is to make the students of Biomedical Engineering familiar with the basic concepts of electric field, magnetic field, wave motion, speed of waves in different media, travelling waves and standing waves. The students will study about lenses, Snell's law, total internal reflection and its applications. The students will learn about cameras, Huygen's principle and its applications. They will study about the potential energy diagram for molecules to understand molecular bonding. They will study free-electron theory of metals and come to know about Fermi energy, Fermi levels, density of states and Fermi Dirac statistics. They will study about semiconductors and impact of doping on semiconductors. They will also study radiations and radiation detectors.

*Recommended Books:*

1. *Dougles, C. Giancoli, Physics of Scientists and Engineers with Modern Physics, ed. 4th, Prentice Hall, 2007.*
2. *H. D. Young and R. A. Freedman, University Physics, ed. 13th Addison-Wesley, 2012*

*CS-141_* **Introduction to Computing: (3+1)**

*Course Outline:*

This course assumes that students coming from different academic backgrounds do not possess prior knowledge and understanding of computer science. It will provide basic knowledge about computers and processing information through computers. It includes topic related to computer hardware and software. Introduction to different streams of computer science will be delivered to students. These streams include computer architecture, software engineering, data structures, operating system, computer networks and databases.

*Recommended Books:*

1. *J. Glenn Brook Shear, Computers Science, An Overview, ed. 12th. Addison Wesley Publishing Company, 2015*
2. *Lesley Anne Robertson, Simple Program Design, ed. 5th Cengage Learning, 2006*

*EE-199_* **Basic Electrical & Electronics Engineering: (3+1)**

*Course Outline:*

This is an introductory course in electronics for Biomedical Engineering students. This course will teach about Ohm's law, equivalent resistance method, nodal analysis of DC circuits loop

analysis of DC circuits, principle of superposition and source transformation, Thevenin, Norton and maximum power transfer theorem. Basics of AC voltage, current and polyphase circuit. Basic of capacitance and inductance. DC generators and DC motors. Introduction to transformers and basics of semiconductor devices.

*Recommended Books:*


1. *Richard Fowler, Electricity: Principles and Applications, ed. 8th Science Engineering & Math, 2013*
2. *J. David Irvin, R. Mark Nelms Basic Engineering Circuit Analysis, ed. 9th Wiley 2008*
3. *Theodore F. Bogart, et al., Electronics Devices and Circuits, ed. 6th. Pearson 2019*


*BME-104_* **Basic Biology: (2+1)**

*Course Outline:*

Biology, Major branches of biology, Three Domains of life. Prokaryotes and Eukaryotes. Chemistry of biomolecules including nucleic acids, lipids, carbohydrates and proteins and their function, Shape of molecule and its function. Cell structure and function i.e. Tour of the cells and its organelles. Cell division including mitosis and meiosis, Regulation of Cell Cycle, Protooncogenes and Tumor suppressors, Cancer, 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, Recombinant DNA technology/Gene cloning, Development and role of cytoplasm and nucleus in development.

*Recommended Books:*


1. *Neil A. Campbell et al., Biology: A Global Approach, ed. 11th, Pearson. 2017*
2. *David E. Sadava, Life, The Science of Biology, ed.10th, W H Freeman and Co,2012*


*MA-110_* **Basic Mathematics: (3+0)**

*Course Outline:*

Complex Numbers, Properties of complex numbers. Conjugates and modulus. Geometrical representation of complex numbers a+ ib. Roots of a quadratic equation (real, distinct, equal and imaginary roots). Formation of quadratic equation when the roots are given. Properties of cube root of unity; $\omega$, $\omega^2$, $1+ \omega + \omega^2 = 0$. Properties, sum, difference and multiplication of matrices. Cramer's rule. Solution of linear equations of three unknowns. Properties: addition, subtraction and multiplication of determinants. Sequence and series. Arithmetic progression, Standard forms of an A. P. Arithmetic means, Geometric progression and Standard forms of a G. P. Sum of Infinite geometric series. Geometric means, Harmonic progression, Harmonic means. Relation between H.M., A.M. and G.M. Expansion of type $(a+b)^n$ for positive integer of 'n'. Use of the general term and determine the middle term or terms of the expansion. Resolve into partial

fractions, Proper and improper fraction. One-one function, Onto function, Even function, Odd function, Exponential function, Trigonometric function, Logarithmic function. Understand the definition of radians and use the relationship between radians and degrees. Basic functions e.g. sine, cosine, tangent etc. relation between them. Trigonometric identities, sum and difference formulae, multiple angle formulae. Express type {a(sinθ) + b(cosθ)} into Rsin(θ +- φ) etc. Inverse functions, Limits: Basic concepts, Limit of form {(sin θ)/ θ} = I; when θ tends to zero. Exponent functions and type $a^x$ etc. Differentiation of $\chi^n$ product and quotient formula. Trigonometric, exponents and logarithmic functions. Differentiation of implicit function, parametric function. Higher order Derivatives, Applications of differentiations. Minima and maxima. Tangent and normal velocity and acceleration. Rate of reaction. Basic Integration. Integrals of sum of powers of 'χ'. Trigonometric, exponent and logarithmic functions. Integration by parts: e.g $\chi\sin\chi$, $\chi e^{\chi}$ and $\log\chi$ etc. Substitution method, Lines, find length, mid-point, gradient of line segment, given the coordinates of end points. Different forms of equation of a line. Angle between two lines, distance of a point from a line.

*Recommended Books :*

1. *FSc. Mathematics Part I*
2. *FSc. Mathematics Part II*

**International Language: (0+0)**

*Zero credit hour course to be offered to students of all Engineering disciplines.*

*BME-101_* **Introduction to Biomedical Engineering: (1+0)**

*Course Outline:*

What is biomedical engineering? Branches of biomedical engineering. Role of biomedical engineer. Biomedical instrumentation fundamental. Critical care devices used in biomedical engineering. Radiological instrumentation. Diagnostic biomedical devices. Therapeutic Biomedical devices. Rehabilitation Engineering. Physiological modelling and simulation. Biomedical signal processing, Clinical Engineering, Biomaterials, Biomechanics, Tissue Engineering and regenerative medicine, Neural engineering, Medical Image Processing.

*Recommended Books:*

1. *John Enderle, Joseph Bronzino, Introduction to Biomedical Engineering, ed. 4th, Academic Press, 2012.*
2. *Joseph. D. Bronzino, Biomedical Engineering Handbook, ed. 3rd , CRC Press Taylor and Francis, 2006.*

*IS-101_* **Islamic & Pak Studies 1: (3+0)**

*Course Outline:*

Islam and basic beliefs, Islamic teachings regarding social behavior, Prophet and his life as a role model. History of Holy Quran, Importance of Hadith. Significance of moral values in the light of the life of the Holy Prophet (PBUH). Concept of Halal and Haram in Islam. Lawful, unlawful and doubtful matters. Islamic rules of purity and cleanliness. Relationship with other religions, Islam and Ethics. Islam and Modern Science. Ideology of Pakistan, Historical background of the ideology of Pakistan and Muslim rule in south Asia. Reformative movements of Shah Wali Ullah and Sir Syed Ahmed Khan. Rise of Political consciousness among Muslims. Non-cooperative movement and Pakistan Movement.

*Recommended Books:*

1. *Selected Surahs and Verses from the Holy Quran*
2. *Arbaeen Nawavi by Abu Zakrya Yahya bin Sharif Al Navawi*
3. *Seerat un Nabi by Shilbi Nomani*
4. *Comprehensive book of Pakistan Studies by M. Ikram Rabbani*

## Semester 2

*BME-102_* **Physiology 1: (2+1)**

*Course Outline:*

The Cell and General Physiology. Functional organization of human body and control of the internal environment. Cell and its function. Quantitative issues at the organ and whole-body levels of cardiovascular. Respiratory, Renal and Digestive systems. Membrane potential, Action potential, Excitation and Rhythmicity. Contraction of Skeletal and cardiac muscles, sliding filament Mechanism, Heart as a pump. Sensory Receptors, Classification and basic mechanism of action. Mechanoreceptive sensations, pain, thermal and visceral pain, headache. Eye, receptor function of the retina, Neurophysiology of Vision, the Chemical Sense-taste and smell.

*Recommended Books:*

1. *Michael Chappell, Stephen Payne, Physiology for Engineers: Applying Engineering Methods to Physiological Systems (Biosystems & Biorobotics), ed. 1st Springer 2016.*
2. *Joseph J Feher, Quantitative Human Physiology: An Introduction (Biomedical Engineering), ed.2nd academic Press. 2017.*
3. *John E. Hall, Guyton and Hall Textbook of Medical Physiology, ed. 13th Saunders, 2015.*

*EE-110_* **Circuit Analysis: (3+1)**

*Course Outline:*

Source Free Series & Parallel RLC Circuits, over- damped, under-damped, critically damped RLC Circuits. Complete response of RLC Circuits, Lossless LC Circuits, Power Factor

Calculations. Nodal, Mesh & loop analysis, Comparison between Nodal and Mesh Analysis. AC source Transformation, Thevenin's, Norton's, Reciprocity & Compensation theorems. Maximum Power Transfer Theorem. First Order Circuits (RL and RC): Transient Response, Steady State Response, Unit Step Response. Introduction to complex frequency damped sinusoidal forcing function, Z (s) & Y (s), frequency response as a function of s, Complex frequency plane, natural response & the S-Plane. Voltage ratio synthesizing, Scaling & Bode Diagrams. General Two Port Networks: Introduction, admittance parameters, some equivalent networks, impedance parameters, hybrid parameters, transmission parameters.

*Recommended Books:*

1. *William, H. Hayt et al., Engineering Circuit Analysis, ed. 7th McGraw Hill Higher Education. 2006.*
2. *Ronald E. Thomas et al., The Analysis and Design of Linear Circuits, ed. 7th John Wiley, 2011.*

*CS-142_* **Programming Fundamentals: (3+1)**

*Course Outline:*

Introduction to flow charts and Pseudo code. First C++ program, Input/Out, data types and basic expressions. Flow chart to conditional statements and loops in C++. Switch statement and arrays. Character arrays, strings and pointers. Introduction to functions, return types and parameters. Passing and returning arrays from functions. Recursion and difference between recursion and iteration. Conversion of iterative algorithms to recursive algorithms. Declaration and usage of structures. File handling and its sequential and random reading. Dynamic memory allocation and dynamic arrays. Difference between structures and classes. Arrays of objects. Case study

*Recommended Books:*

1. *D. S. Malik, C++ Programming: From Problem Analysis to Program Design, ed. 8th Cengage Learning 2017*
2. *Jhon R. Hubbard, Schuam's Outline of Programming with C++, ed. 2nd McGraw-Hill Education, 2000.*
3. *Paul, J. Deitel, C++, How to Program, ed. 10th Pearson, 2014.*

*MA-113_* **Calculus & Analytical Geometry: (3+0)**

*Course Outline:*

A review of differentiation and geometrical interpretation of a derivative. Differential coefficients, derivatives of higher order and L'Hopital Rule. Integration by reduction formula, fundamental theorem of Integral calculus, Definite integral and its properties, Area enclosed between curves, Arc length and volume of a solid of a revolution. Moments and Centroids. Cartesian, cylindrical and spherical coordinates. Direction ratio and direction cosines. Angle between two straight lines. Equations of plane and angle between two planes. Directional derivatives. The concept of limit, continuity and differentiation in functions of several variables. Geometric interpretation of partial derivatives. Total differential, chain rule, implicit differentiation. Maxima and Minima of functions of two independent variables. Taylor's and

McLaren series for functions for two variables. Double integration. Fubini's theorem and change of order. Geometrical interpretation of double integral. Applications to find volumes and areas.

*Recommended Books:*

1. *Erwin Kreyszig, Advanced Engineering Mathematics, ed. 8th Willey, 1999.*
2. *George, B. Thomas, and Ross, L. Finny Calculus and Analytic Geometry, ed. 9th Addison-Wesley, 1995.*

*BME-103_* **Human Anatomy: (2+1)**

*Course Outline:*

Introduction, Anatomy and its branches, Anatomical positions, Planes, Topography. Cell Anatomy, Overview of Cellular Anatomy. Extremities (Upper and lower), Bones, Muscles, Ligaments, Tendons, Bursae, Reticulate, Capsules, Arteries, Veins, Lymphatic system. Vertebral Anatomy, Vertebrae, Pelvic girdle, Spinal cord, Nervous system. Thorax-Thoracic Viscera, Surface anatomy, Bones surface musculature, Lungs, Heart. Abdomen, Organs location, Structures, Relations and function. Head & Neck, Bones, Muscles, Cranial nerves

*Recommended Books:*

1. *Bonnie, F. Fremgen and Suzanne. S. Frucht, Medical Terminology: A Living Language, ed. 6th Pearson 2015.*
2. *Aydin Tozeren and Stephen W. Byers, New Biology for Engineers and Computer Scientists, ed. 1st Pearson, 2003.*
3. *Gerard J. Tortora, Principles of Human Anatomy, ed. 12th Wiley, 2010*

*ME-124L_* **Engineering Drawing: (0+1)**

*Course Outline:*

Introduction, Introduction to Engineering Drawing, Use of drawing instruments and materials. Basic Tools- classification and brief description. Lines, Types of lines, configuration of lines and their application, Selection of line thickness. Engineering Geometry, Geometric construction, Coordinate systems, Basic entities, Drawing simple geometric objects, Introduction to different types of scales. Modelling Fundamentals, Introduction to solid modelling. Multiview and Visualization, Projection theory, Projection of principal views from 3D models, Orthographic projections, Isometric drawings, Section views. Dimensioning and plotting, Dimensioning, Plotting and printing.

*Recommended Books:*

1. *Roop Lal, Ramakant Rana, A Textbook of Engineering Drawing: Along with an Introduction to AutoCAD, ed. 1st I K International Publishing House Pvt. Ltd, 2015.*

2. *Curtis, Waguespack, Mastering Autodesk Inventor 2015 and Autodesk Inventor LT 2015: Autodesk Official Press, ed. 1st Wiley, 2014.*
3. *Thomas E. French, et al., Engineering Drawing and Graphic Technology ed. International 14 Revised Edition, McGraw-Hill Education, 1993.*

## Semester 3

*MA-116_* **Linear Algebra & Differential Equations: (3+0)**

*Course Outline:*

A review of matrices, determinants and finding inverse of a matrix through elementary row elimination. Solution of system of linear equations, Euclidean space, vector space and subspaces. Linear independence and Dependence, Basis and dimensions. Normed spaces and inner product spaces. Angle and orthogonality in inner product spaces, Orthogonal basis and linear transformations. Kernel and range, Inverse linear transformation, Eigenvalue and eigenvectors. Applications to relevant problems. Formation of differential equations and orthogonal trajectories. Complementary function and integral trajectories. Solution of non-homogenous linear differential equations of second order and higher by different methods. Laplace transform and Fourier transform. Even, odd and periodic functions.

*Recommended Books:*

1. *David C. Lay and Steven R. Lay, Linear Algebra and Its Applications, ed. 5th Pearson, 2015*
2. *Bernard Kolman and David Hill, Elementary Linear Algebra with Applications, ed. 9th Pearson, 2007.*
3. *Erwin Kreyszig, Advanced Engineering Mathematics, ed. 10th Wiley, 2011*

*BME-201_* **Physiology 2: (2+1)**

*Course Outline:*

Nervous System and 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. Somatic Sensations, Mechanoreceptive sensations, Pain, Thermal and visceral pain, Headache. Behavioral functions of the Brain, Limbic System, Role of the Hypothalamus, 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 and the pituitary Hormones, Hormonal functions in male and female, Vestibular control of postural reflexes, Cerebrum and basal ganglia, Reticular. Somatic Sensations, Mechanoreceptive sensations, Pain, Thermal and visceral pain, Headache. Behavioral functions of the Brain, Limbic System, Role of the Hypothalamus, 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 and the pituitary Hormones. Hormonal functions in male and female

*Recommended Books:*


1. *John E. Hall, Guyton and Hall Textbook of Medical Physiology, ed. 13th Saunders, 2015.*
2. *K Sembulingam, Essential of Medical Physiology, ed.6th Jaypee Brothers, Medical Publishers Pvt. Ltd, 2012.*
3. *William Ganong, Review of Medical Physiology, ed. 22nd McGraw-Hill Medical, 2005*


*BME-214_* **Biochemistry: (2+1)**

*Course outline:*

Brief Overview of structure and function of biomolecules, Introduction to Metabolism and its types, Bioenergetics and biochemical reaction types, How ATP powers cellular work. Enzymes: How enzymes speed up metabolic reactions, Regulators of enzymes including physical factors and proteins like Allosteric Regulators, Competitive Inhibitors and Non-competitive Inhibitors, Three dimensional structures of proteins, X-ray and NMR structures, Protein misfolding and disease, working with proteins, Carbohydrates and Glycobiology, Biosynthesis of Carbohydrates and Lipids, Glycolysis, Gluconeogenesis and pentose phosphate pathway, Citric Acid cycle/Tricarboxylic acid cycle, Amino acids Oxidation, Oxidative phosphorylation, Fatty acid metabolism, Metabolic regulation, Hormonal regulation in mammalian metabolism.

*Recommended Books:*


1. *David L. Nelson and Michael M. Cox, Lehninger Principles of Biochemistry, ed. 6th W.H Freeman, 2012.*
2. *Neil A. Campbell et al., Biology: A Global Approach, ed. 11th, Pearson. 2017*
3. *Donald Voet et al., Fundamentals of Biochemistry, ed. 5th John Wiley & Sons Inc, 2016.*


*EE-212_* **Semiconductor Devices: (3+1)**

*Course outline:*

This introductory course will cover the basic concepts involved in constructions, operations, and characteristics of semiconductor devices used in analog and digital electronic circuits. The semiconductor physics, starting from atomic structure to impurity doping process will be studied. The students will learn to quantitatively analyze the characteristics of doped material with different types, doping and fermi level concept, density of states, energy band diagrams. Concept of charge neutrality. The characteristics of an ideal diode and its nonlinear behavior in circuits

will be discussed. The modeling of real diode using ideal devices will be introduced. The students will be introduced with use of diodes in electronic circuits and will be able to analyze and design the diode circuit applications in real electronic systems. The students will also be introduced to construction and characteristics of BJTs and FETs and biasing techniques. The use to semiconductor devices in special applications will also be discussed.

*Recommended Books:*

1. *Theodore F. Bogart Jr, Electronic Devices and Circuits, ed. 3rd Prentice Hall Professional Technical Reference, 1992.*
2. *Robert F. Pierret, Advanced Semiconductor Fundamentals, ed. 2nd Pearson, 2002.*

*ME-100L_* **Workshop Practice: (0+1)**

*This course is mandatory as per UET to be offered to students all Engineering disciplines. Course has already been approved by academic council.*

*HU-111L_* **Communication Skills: (0+1)**

*Course Outline:*

This is a practical course which 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 which affect both interpersonal and inter-organizational dealings.

*Recommended Books:*

1. *Rutherford A. J. Basic Communication skills for Technology, ed. 2nd Prentice Hall, 2000.*
2. *Herbert W. Hildebrandt, et. al., Effective Business Communications, ed. 7th Tata McGraw-Hill Education Pvt. Ltd., 2008.*

*IS-201_* **Islamic & Pak Studies 2: (3+0)**

*Course Outline:*

Characteristics of the righteous people. Advices of Luqman as a wise man. Scientific study of the universe and pillars of the Islam. Striving in the cause of Allah. Social manners, Obligations on a Muslim for a Muslim. History and Compilation of Hadith. Islam and Ethics. Prophetic life as role model. National Integration of Pakistan. Initial problems of Pakistan and steps to overcome them. Land and resources of Pakistan. State and constitution of Pakistan. Pakistan and Human Rights. Foreign policy of Pakistan and its relations with its neighbors. Islamic criminal Law. Relations of Pakistan with Muslim world. Pakistan and contemporary world. Pakistan and regional organizations.

*Recommended Books:*

1. *Selected Surahs and Verses from The Holy Quran*
2. *Hafiz Ibn Hajar Al-Askalani, Buloog Ul Maram, 2015*
3. *Shibli Nomani and Sulaiman Nadvi, Seerat ul Nabi, Darul Ishaat, 2007*
4. *M. Ikram Rabbani, Comprehensive Book of Pakistan Studies, ed. 3rd, Carvan Book House, 2005*

## Semester 4

*BME-202_* **Cellular and Molecular Biology: (2+1)**

*Course Outline:*

Introduction, Gene structure and organization, Gene Expression i.e. Transcription and Translation. Transcription in prokaryotes and eukaryotes, The Genetic Code, Codon & Anticodon concept, DNA damage and repair, DNA Recombination and Transposition, Control of gene expression in prokaryotes and eukaryotes, Operon concept, Activators and repressors, Chromatin and organization of DNA within cell and its role in regulation of gene expression, Mutagenesis & Mutations. Noncoding RNAs and their importance, Cell to cell communication and cell signaling, Different types of cell signaling and signaling molecules, Ligands and Receptors, Phagocytosis and endocytosis, Pathogens and mechanism of diseases, Innate immune system and adaptive immune system, Antibodies and vaccines, Stem cell and Gene Therapy.

*Recommended Books:*

1. *Bruce Alberts, Molecular Biology of the Cell, ed. 6th Garland Science, 2018.*
2. *Benjamin Lewin, Gene IX, ed. 9th Jones and Bartlet Publishers, 2009*
3. *Brian M. Turner, Chromatin and Gene Regulation, ed. 2nd, Wiley Blackwell, 2008*

*MA-221_* **Complex Variable & Transformation: (3+0)**

*Course Outline:*

The complex number and complex variables, Complex differentiation and integration, Laplace Transformation and its applications, Series solution of the DEs, Complex number systems and Complex Variable theory, Introduction to complex number systems, Argands diagram, modulus and argument of a complex number, Polar form of a complex number, De Moivres theorem and its applications, Complex functions, analytical function, harmonic and conjugate harmonic functions, Cauchy-Remann equations (in Cartesian and polar coordinates). Line integral, Greens theorem, Cauchys theorem, Cauchys integral formula, Singularities, poles, residue and contour integration and application. Laplace Transforms, Laplace transforms of elementary functions, Properties of Laplace transform, Laplace transform of derivatives, integrals, Multiplication by t and division by t properties, Periodic functions and their Laplace transforms, Inverse Laplace transforms and their properties, Convolution theorem, Inverse Laplace transforms by integral and partial fraction methods, Heaviside expansion formula, Solution of ordinary differential equations by Laplace transform, Applications of Laplace transformation on various fields of

engineering. Series Solution of Differential Equations, Introduction, Validity of series solution, Ordinary point, singular point, Forbenius method, Indicial equation, Bessels differential equation, its solution of first kind and its recurrence formulae, Logendre differential equation and its solution, Rodriguez formula. Fourier Transform, Fourier transform of simple functions, Magnitude and phase spectra, Fourier transform theorems, Inverse Fourier transform, Solution of differential equation using Fourier transform

*Recommended Books:*


1. *Erwin Kreyszig, Advanced Engineering Mathematics, ed. 10th Wiley, 2011.*
2. *Robert L. Borrelli and Courtney S. Coleman, Differential Equations: A Modeling Perspective, ed. 2nd Wiley, 2004.*
3. *Dennis G. Zill and Warren S. Wright, Differential Equations with Boundary- Value Problems, ed. 8th Brooks Cole, 2012.*


*BME-213_* **Biomedical Electronics: (2+1)**

*Course Outline:*

Operational Amplifiers, Analysis of OP-AMP action, OP-AMP specifications, Interpreting OP-AMP data sheet, Offset voltage and current, Temperature rating, Output swing, Gain, CMRR. Basic OP-AMP Configuration Circuits, inverting amplifiers, non-inverting amplifiers, Voltage follower, Summing amplifiers, Integrator and differentiator. Instrumentational Amplifier, Sensing and Measuring with the instrumentation amplifier, Instrumentation amplifier as a signal conditioning circuit. Active Filters Design. Basic Low Pass filters, Introduction to Butterworth filters, High pass and Bandpass Butterworth filters, Notch filters. A/D and D/A converters. Selected Applications of OP-AMPs in Biomedical Engineering. Signal Acquisition and Conditioning of ECG using OP-AMPs.

*Recommended Books:*


1. *Thomas, L. Floyd, Electronics Design, ed. 9th Pearson, 2012.*
2. *Robert F. Coughlin , Frederick F. Driscoll, Operational amplifier and linear integrated circuits, ed. 6th Pearson 2000.*


*CSE-221_* **Digital Logic Design: (3+1)**

*Course Outline:*

This course introduces students to the fundamentals of logic design and computer hardware entailing logic gates, logic circuits, truth tables, boolean algebra, synthesis using AND, OR and NOT gates, NAND and NOR logic networks, optimized implementation of logic functions, design of logical circuits. Small, medium and large-scale integrated circuits entailing combinational circuits such as decoders, multiplexers and arithmetic circuits, sequential circuits such as flip-flops, registers, counters, and static memory. Students will be introduced to CAD

tools (Verilog), and will be able to design a simple microprocessor accompanied by an introduction to assembly language.

*Recommended Books:*

1. *M. Morris Mano, Digital Logic & Computer Design, ed. 1st Pearson College Div, 1979.*
2. *Morris M. Mano and Michael D. Ciletti, Digital Logic Design With an Introduction to the Verilog HDL, ed. 5th Pearson, 2012.*

*EE-220_* **Signals & Systems: (3+0)**

*Course Outline:*

Continuous time signals, discrete time signal, even, odd and period signals. Complex exponential and sinusoids in continuous-time and discrete-time, unit step and unit impulse. Basic properties of signals and systems, LTI and impulse response. Discrete and continuous time convolution. Difference equations and its solution. Eigenfunction property of complex exponentials, Continuous time Fourier series (CTFS). Convergence, Gibbs phenomenon, properties of Fourier series and Discrete time Fourier series (DTFS). Continuous time Fourier transform and frequency response. Definition of discrete time Fourier transform and its relation to Fourier series. Definition of Z-transform and region of convergence. Properties of Z-transform and characterization of linear time invariant systems. Definition of discrete Fourier transform and frequency domain sampling. Properties of DFT.

*Recommended Books:*

1. *Gorden E. Carlson, Signal and Linear System Analysis, ed. 2nd John Wiley & Sons, Inc. 1992.*
2. *Oppenheim, Alan V., and A. S. Willsky, Signals and Systems, ed. 2nd Prentice Hall, 1982.*
3. *B. P. Lathi, Linear Systems and Signals, ed. 2nd, Oxford, 2004.*

## Semester 5

*BME-310_* **Biomedical Instrumentation 1: (2+1)**

*Course Outline:*

Introduction to measurements, Precision, Resolution, Sensitivity, Accuracy, Uncertainty. Bio-potentials, biosensors and transducers, Biomedical signals of the human body, Sensors and transducers for bio-potential measurements, Problems encountered in measuring biopotentials of the human body, Invasive and noninvasive measurement techniques and related equipment, Functional Building blocks of a Biomedical Instrumentation System. Cardiovascular System Devices, Diagnostic Electrocardiography, Measurement of Blood pressure, Blood flow, Therapeutic: Cardiac output. Defibrillator, pacemaker. Pulmonary System Devices, Diagnostic: Pulmonary Function Analyzer, Spirometry, Ventilation Monitors, Respiration: Pulse oximetry, Capnography, Therapeutic Ventilators, Heart lung machine, nebulizer. Musculoskeletal &

Nervous System Devices, EMG, EEG. Critical Care Devices, Patient Monitoring**:** Patient Monitors, central monitoring system, telemetry system, Surgical/Operation Theatre Devices Equipment**:** Electrosurgical unit. Genito-urinary System Devices, Hemodialysis Machine.

*Recommended Books:*

1. *Leslie Cromwell, et.al., Biomedical Instrumentation & Measures, ed. 2nd Prentice Hall PTR, 1980.*
2. *John G. Webster, Bioinstrumentation, ed. 1st Wiley, 2003.*
3. *John G. Webster, Medical Instrumentation: Application and Design, ed. 4th Wiley 2009*

*EE-320_* **Applied Probability & Statistics: (3+0)**

*Course Outline:*

Axiomatic probability theory and independent events. Total probability theorem and Bayes' theorem and conditional probability. Random variables, distribution and density function of a single and multiple random variables. Conditional distribution/density function and independence. Moments or two or more random variables. Moments of sum of random variables. Characteristics functions. Important discrete and continuous distributions. Function of one and two random variables. Sum, product, random vector, correlation and covariance matrices. Mean square estimation. Introduction to wide-sense and strict-sense stationarity. Second moment theory.

*Recommended Books:*

1. *Athanasios Papoulis and S. U. Pillai, Probability, Random Variables, and Stochastic Processes, ed. 4th McGraw Hill, 2002.*
2. *Dimitri P. Bertsekas and John N. Tsitsiklis, Introduction to probability, ed. 2nd Athena Scientific, 2008.*

*MA-346_* **Numerical Methods: (3+0)**

*Course Outline:*

Error analysis, Floating points, Errors and types of errors. Solution of non-linear equation, Bisection, Regula-Falsi, Fixed-point iterative and Newton-Raphson's methods, Solution of linear algebraic equations. Direct methods, Crout's and Cholescky methods. Iterative methods, Jaccobi's and Guass-Seidal methods. Eigen values and eigen vectors, Characteristics equation and Power methods. Interpolations and extrapolations, Forward, backward, central difference operators and their relations. Newtons Forward, Backward and Divided Difference Interpolation Formulae. Lagrange's and Stirling's Interpolation Formulae. Numerical differentiation, Newton's-Forward and Backward differentiation Formulae. Numerical quadrature, Trapezoidal, Simpson's one-third, Simpson's three-eight and Weddle's rules and Gaussian quaderature. Solution of OD Eqns, Taylor Series, Euler's and its modified, Runge-Kutta, Miline's, Adam-Moltan (Predictor-Corrector) methods. Solution of Higher Order Differential Equations, Runge-Kutta methods. Solution of Partial Differential Equations by Finite Differences Methods (Explicit, Implicit and Crank-Niclson techniques) and ADI Method.

*Recommended Books:*

1. *Dunn, Stanley et. al., Numerical Methods in Biomedical Engineering, ed. 1st Academic Press, 2006.*
2. *Chapra, Numerical Methods for Engineers, ed. 5th McGraw-Hill Education, 2005.*
3. *Curtis, F. Gerald and Patrick, O. Wheatley, Applied Numerical Analysis, ed. 7th Pearson, 2003.*

*EE-273_* **Microprocessor Systems: (3+1)**

*Course Outline:*

Introduction to the course. Embedded systems, microprocessor vs microcontroller, classification of processor architectures and development tools. Why ARM architecture? Introduction to ARM cortex M3, architecture, registers, ALU, Buses, Operating modes, memory MAP, reset sequence, pipelining. Why assembly programming? Introduction to cortex-M assembly programing. Shift and arithmetic operations, other useful data processing instructions. Memory access instructions, use of stack and parameter passing, memory addressing modes. Branch instructions, unconditional and conditional branches, functions. Introduction to ARM based microcontrollers, I/O, Tiva C I/O pins, basic concepts of I/O ports and interfacing, clock sources and clock configuration, the concept of PLL. Interrupt configuration, interrupt vector table, interrupt handling, Peripheral and nested interrupts. Timer and PWM. Serial communication (asynchronous UART and synchronous SPI, I2C), basic configuration, polling and interrupt driver transmission.

*Recommended Books:*

1. *M. Tahir and K. Javed, ARM Microprocessor Systems: Cortex-M Architecture, Programming and Interfacing, ed. 1st CRC press, 2017.*
2. *Jonathan W Valvano, Introduction to Embeded systems: Introduction to ARM Cortex-M Microcontrollers, ed. 5th CreateSpace Independent Publishing Platform, 2012.*

*BME-313_* **Biomaterials: (2+1)**

*Course Outline:*

Overview of Biomedical Materials, Introduction and historical developments. Requirements and Classification of Biomedical Materials. Today's biomaterials applications: overview of types of implantable biomaterials and devices. Properties of Biomaterials: General Concepts: Bonding, interatomic, intermolecular, surface interactions**,** Introduction to bulk properties: microstructure, strength, deformation, thermal and optical properties**.** Biomedical metals in Orthopedic and Dentistry. Biomedical Ceramic, Structure-Property Relationship, Formation & Properties of Aluminum Oxides, Calcium Phosphates, Glass-Ceramics, Biomedical ceramics in Hard Tissue and Soft Tissue Replacements, Biomedical ceramics in Orthopedic, Dentistry. Polymeric biomaterials, chitosan, collagen, elastin, proteoglycan and glycoprotein), basic principles: molecular and chemical structure, molecular weight and polydispersity, physical behavior, synthesis: addition, free-radical, condensation polymerization, Hydrogels: structure and synthesis, examples of biomedical hydrogels: acrylic, PVA, PEG, degradable, smart hydrogels etc. Composites in biomedical application. Mechanical properties and testing of materials,

Characterization of Materials. Failure of Engineering Materials, Fracture & Fatigue, Wear & Degradation/Corrosion. Biocompatibility and Biological Tests, Definition. Biocompatibility tests and their rules. Biological tests – Cytotoxicity, Genotoxicity, Carcinogenicity, Reproductive Toxicity, Infection and sterilization. Tissue Engineering, gene therapy using viral vector materials for scaffolding.

*Recommended Books:*


1. *Donglu Shi, Introduction to Biomaterials, ed. 1st World Scientific/Tsinghua University Press, China, 2006.*
2. *Swee Hin Teoh, Engineering Materials for Biomedical Applications, ed. Illustrated reprint, World Scientific, 2004.*
3. *Kay C. Dee, et al, An Introduction to Tissue-Biomaterial Interactions, ed. 1st Wiley-Liss, 2002*


## Semester 6

*BME-212_* **Biomechanics: (2+1)**

*Course Outline:*

Introduction, Definition and perspective, Review of statics, Review of Dynamics, Review of deformable body mechanics, Viscoelasticity, material properties. Anthropometry, Density, mass and inertial properties, Direct measurement of anthropometric parameters, Muscle anthropometry, Mechanical advantage of muscle, Multipoint muscles. Kinematics of Human Movement, Forms of motion, Standard reference systems and joint movement terminology, Spatial reference systems, qualitative vs. quantitative analysis of human movement, limb-segment angles, joint angle, linear and angular velocities and acceleration, tools for direct/indirect measurement of kinematic quantities. The biomechanics of Human Bone Growth and Development, Composition and Structure of Bone Tissue, Material Constituents, Structural Organization, Types of Bones, Bone Growth and Development, Longitudinal Growth, Circumferential Growth, Adult Bone Development, Bone Response to Stress, Bone Modeling and Remodeling, Bone Hypertrophy, Bone Atrophy, Osteoporosis. Kinetics of Human Movement, Link segment models, Joint reaction forces, Direct Force measurements. Biomechanics of upper & lower extremity, Loading and injuries to the shoulder, elbow, wrist joints, Loading and injuries to the Hip, knee and ankle joints. Gait Biomechanics, Methods of gait analysis, Gait cycle, Temporal-spatial parameters, Hip, knee and ankle joint kinematics and kinetics, Interpretation of gait data.

*Recommended Books:*


1. *Susan J. Hall, Basic Biomechanics, ed. 6th McGraw-Hill Higher Education, 2011.*
2. *Nordin DirSci, Margareta and Frankel, Victor H. Basic Biomechanics of the Musculoskeletal System, ed.4th LWW, 2012*
3. *Nihat, Ozkaya, et. al., Fundamentals of Biomechanics: Equilibrium, Motion, and Deformation, ed. 4th Springer, 2017.*

*BME-318_* **Biomedical Instrumentation 2: (2+1)**

*Course Outline:*

Centrifugation techniques. Electrochemical methods of analysis, Electrophoresis, Blood banking and transfusion, Chromatography, Liquid chromatography, Gas chromatography, High performance liquid chromatography, Clinical chemistry analyzer, Automated cell counter. Spectroscopy, Spectrophotometry, Flame photometry, Mass spectrometry, Infrared spectrometry, Nuclear Magnetic Resonance Spectroscopy. Microscopy, Electron microscopy, Atomic force microscopy, Confocal microscopy. Quality Assurance and Quality Control, Common defects in medical equipment, Performance measurement, Calibration, Maintenance and repair.

*Recommended Books:*

1. *Mary C. Haven, et. al., Laboratory Instrumentation, ed. 4th Wiley 1994.*
2. *Cromwell, Biomedical Instrumentation & Measures, ed. 2nd Prentice Hall India Learning Private Limited, 1990.*
3. *John G. Webster, Medical Instrumentation Application and Design, ed. 4th Wiley, 2011.*

*BME-XXX_* **Technical Elective 1: (3+0)**

*Course Outlines of Electives are given in separate section at the end of 8th semester.*

*EE-340_* **Control Systems: (3+1)**

*Course Outline:*

Fundamentals of control systems, close loop versus open loop control, mathematical modeling of dynamic systems. Transfer function, block diagram, block diagram reduction. Modeling in state space, state space representation of dynamic systems. Differential equations of physical systems and their linear approximation, electrical and mechanical system modeling examples, problem discussions. Transient response analysis for second and higher order systems, steady state response for second and higher order systems. Routh Hurwitz stability criterion. Unity feedback system, effect of integral and derivative control actions, PID control and its tuning. Basic concept of root locus method and its procedure. Control system design by root locus, lead and lag compensation. Parallel compensation. Frequency response analysis. State space analysis.

*Recommended Books:*

1. *Norman S. Nise, Control Systems Engineering, ed.7th John Wiley & Sons,2007.*
2. *Mei, Katsuhiko Ogata, Modern Control Engineering, ed. 5th Publishing House of Electronics Industry, 2011.*

*BME-244_* **Biomedical Modeling & Simulation: (2+1)**

*Course Outline:*

Basics of Modeling and Simulation, Simulation in Real Systems. Modeling in Biomedical engineering Time and events-oriented processes, Hierarchical and integrated Models. Types of Models e.g. graphical model, Quantitative models. Mathematical Models and their importance in biomedical engineering. Mathematical models of Mechanical and Electrical systems. Electrical modeling of physiological System. Review on Probability & Statistics. -Matrix Manipulation and Linear Algebraic Systems. Random Variables & Stochastic Processes. Gaussian Functions & their Properties, Correlation Analysis, Time Series Modeling, Regression Modeling and Biomedical Signal Modeling.

*Recommended Books:*


1. *Willem L. van Meurs, Modeling and Simulation in Biomedical Engineering, ed. 1st McGraw-Hill Education, 2011.*
2. *John Enderle, Joseph Bronzino, Physiological Modeling: An Introductory Course for Biomedical Engineers, ed. 3rd Academic Press, 2011.*
3. *W. J. Minkowycz, Advances in Numerical Heat Transfer, ed. 1st CRC Press, 2017.*


## Semester 7

*MGT-XXX_* **Management Elective 1: (3+0)**

*Course Outlines of Electives are given in separate section at the end of 8th semester.*

*BME-411_* **Medical Imaging: (2+1)**

*Course Outline:*

X-ray Imaging, Physics of X-ray, Imaging with X-ray, Radiation dose, Attenuation based X-ray Imaging, X-ray Detection, X-ray Image Quality, Diagnostic Applications of X-ray Imaging, Demonstration of X-rays Equipment. Principles of Computed Tomography, Introduction to Computed Tomography and Scanners, Attenuation Tomography, Time of Flight Tomography, Reflection Tomography, Diffraction Tomography, Formulation of Attenuation Computed Tomography, Fourier Slice theorem. Magnetic Resonance Imaging, Physical and physiological principle of Magnetic Resonance Imaging, MR Imaging, Formulation of MRI reconstruction, Functional MRI, BOLD MRI, Applications of MRI and fMRI. Ultrasound Imaging, Generation and detection of ultrasound waves, Physical and physiological principles of Ultrasound, Resolution of Ultrasound imaging, Ultrasound Imaging Modalities, Doppler Ultrasound Imaging, Modes of ultrasound image representation, Ultrasound Image Artifacts. Positron Emission Tomography, Physical and physiological principles of PET, PET Signal Acquisition, PET Image formation, Significance of PET, Applications of PET.

*Recommended Books:*


1. *Jerrold T. Bushberg, et. al., The Essential Physics of Medical Imaging, ed. 3rd LWW, North American edition, 2011.*

2. *Z. H. Cho, et. al., Foundations of Medical Imaging, ed.1st Wiley-Interscience, 1993.*
3. *Geoff, Dougherty, Digital Image Processing for Medical Applications, ed. 1st Cambridge University Press, 2009.*

*BME-XXX_* **Technical Elective 2: (3+0)**

*Course Outlines of Electives are given in separate section at the end of 8th semester.*

*BME-XXX_* **Technical Elective 3: (3+0)**

*Course Outlines of Electives are given in separate section at the end of 8th semester.*

*HU-221_* **Technical Writing & Presentation Skills: (3+0)**

*Course Outline:*

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. *Paul V. Anderson, Technical Communication. A Reader Centered Approach, ed. 7th Wadsworth, 2003.*
2. *Sharon J. Gerson and Steven M. Gerson, Technical Writing Process and Product. ed. 5th Pearson education Inc, 2006.*

*BME-412a_* **Biomedical Engineering Project Phase 1: (0+3)**

## Semester 8

*BME-XXX_* **Technical Elective 4: (3+0)**

*Course Outlines of Electives are given in separate section at the end of 8th semester.*

*BME-XXX_* **Technical Elective 5: (3+0)**

*Course Outlines of Electives are given in separate section at the end of 8th semester.*

*BME-XXX_* **Management Elective 2: (3+0)**

*Course Outlines of Electives are given in separate section at the end of 8th semester.*

*IME-251_* **Social & Ethical Aspects in Engineering: (2+0)**

*Course Outline:*

Introduction, overview and scope of social and ethical aspects in engineering. Ethics and professionalism: Overview and scope, accepting and sharing responsibility. Importance, limitations, abuse and justification of codes. Ethical dilemmas and making moral choices and case study. Moral frameworks, Utilitarianism, right, duty, virtue ethics and case study. Engineering society & Environment: Socially conscience engineering, corporate social responsibility, Introduction to social accountability. Ecology and economics, Safety and Risk (Human, machine, system and environment perspective). Commitment to safety, assessing and reducing risk, a case study. Workplace responsibilities and rights: teamwork, confidentiality and conflict of interest. Honesty: Trustfulness and Trustworthiness, a case study. Honesty: Expert witnesses and advisors, research integrity. Global issues: Technology transfer, computer ethics, internet and workforce diversity.

*Recommended Books:*


1. *Evans, J.R. & Lindsay, W.M., Management and Control of Quality, ed. 8th West Publishing, 2011.*
2. *Margaret A. White and Garry D. Bruton, The Management of Technology and Innovation: A Strategic Approach, ed. 2nd Mason, OH South-Western Cengage Learning, 2011.*
3. *Jack R. Meredith, et. al., Project Management: A Managerial Approach, ed. 10th Wiley, 2015,*


*BME-412b_* **Biomedical Engineering Project Phase 2: (0+3)**

## Course Outlines of Technical Electives

*BME-314_* **Bioelectricity: (3+0)**

*Course Outline:*

Introduction and Excitation Model, the course will include the Impedance and Current Distribution, Electrical Principles of Nerve and Muscle Function, Excitation Models. Electrical Stimulation, Electrical Properties of the Heart, Cardiac Sensitivity to Electrical Stimulation, Sensory Responses to Electrical Stimulation, Skeletal Muscle Response to Electrical Stimulation, Stimulation via Electric and Magnetic Fields, Deep Brain Stimulation, Electroconvulsive therapy. Application of Electrical Stimulation, TENS for pain management, TENS equipment, techniques, and biophysical principles, Appropriate electrode sites and electrical characteristics for TENS, Mechanism of action of TENS, the use of TENS for non-painful conditions, Functional electrical Stimulation, Bio-signal control based electrical stimulation.

*Recommended Books:*

1. *Reilly, J. Patrick, Applied Bioelectricity: From Electrical Stimulation to Electro pathology, ed. 1st, Springer, 1998.*
2. *Mark I. Johnson, Transcutaneous Electrical Nerve Stimulation (TENS): Research to support clinical practice, ed. 1st, Oxford University Press, 2014.*

*EE-392_* **Power Electronics: (2+1)**

*Course Outline:*

This course will cover the design and analysis of power electronic converters such as diode rectifiers, semi-controlled and fully controlled rectifiers, single phase and three phase inverters. Buck, boost and buck-boost regulator (switch mode power supplies); AC to AC controllers, cyclo-converters and PWM rectifiers. Power quality analysis of converter circuits, thermal design consideration and characteristics of power switches such as thyristor. Moreover, power BJTs and MOSFETs will be discussed in detail.

*Recommended Books:*

1. *N. Mohan et al., Power Electronics: Converters, Applications, and Design, ed. 3rd, John Wiley & Sons, 2003.*
2. *M. H. Rashid, Power Electronics: Circuits, Devices, and Applications, ed. 4th, Prentice Hall, 2014.*
3. *M. D. Singh and K.B. Khanchandani, Power Electronics, ed. 2nd, Tata McGraw-Hills Publishing Company Limited, 2006.*

*BME-433_* **Rehabilitation & Sports Medicine: (2+1)**

*Course Outline:*

Introduction, Introduction to rehabilitation engineering and assistive technology (AT), Domains of rehabilitation engineering, Future of rehabilitation engineering. 3D modeling, Limb Prosthetic Devices, Classification of amputation, Prosthetic prescription and fabrication, Components of upper limb prosthesis, Components of lower limb prosthesis. Orthotic Devices, Introduction, Biomechanical principles of orthoses, Design consideration, Spinal orthoses, Limb orthoses. Devices for Visually Impaired, Dimensions of visual impairment and their impact on task performance, General purpose assistive technology solutions, Task-specific assistive technologies, Technology for reading, Writing and graphic access. Devices for Hearing Impairment, Types of hearing impairment, Historical overview of HAT (Hearing assistance technology), Medical and surgical approaches to restoring hearing function, Assistive listening devices solutions, Environmental adaptations and universal designs. Wheelchairs, Manual wheelchairs and electrical power wheelchairs with brief history, User profiles, Basic structural components, Power and drive systems, Control system, Power assisted wheelchairs, Multifunctional wheelchairs, Wheelchair standards. Neurorehabilitation, Functional Electrical Stimulation, Transcutaneous Electrical Stimulation, Brain Computer Interface, Assessment methods for neurorehabilitation.

*Recommended Books:*


1. *Rory A Cooper et al., An Introduction to Rehabilitation Engineering, ed.1st, Tylor & Francis Group, 2006.*
2. *Pedro Encarnaçao and Albert Cook, Robotic Assistive Technologies: Principles and Practice, ed. Ist, CRC Press, 2017.*
3. *Kevin Russell Henderson, Wheelchairs: Perceptions, Technology Advances and Barriers, UK ed. , Nova Science Publishers Inc, 2016.*


*BME-414_* **Biomedical Robotics: (2+1)**

*Course Outline:*

Fundamentals, what is a Robot? Classification of Robots. What is Robotics? History of Robotics. Advantages and Disadvantages of Robots. Robot Components. Robot Degrees of Freedom. Robot Joints. Robot Coordinates. Robot Reference Frames. Programming Modes. Robot Characteristics. Robot Workspace. Robot Languages. Robot Applications. Other Robots and Applications. Social Issues. Robot Kinematics. Position Analysis. Robots as Mechanisms. Matrix Representation. Homogeneous Transformation Matrices. Representation of Transformations. Inverse of Transformation Matrices. Forward and Inverse Kinematics of Robots. Denavit-Hartenberg Representation of Forward Kinematic Equations of Robots. The Inverse Kinematic Solution of Robots. Inverse Kinematic Programming of Robots. Degeneracy and Dexterity. The Fundamental Problem with the Denavit-Hartenberg Representation. Differential Motions and Velocities. Differential Relationships. Jacobian. Differential Motions of a Frame. Interpretation of the Differential Change. Differential Changes between Frames. Differential Motions of a Robot and Its Hand Frame. Calculation of the Jacobian. How to Relate the Jacobian and the Differential Operator. Inverse Jacobian. Design Project. Dynamic Analysis and Forces. LaGrange Mechanics. A Short Overview. Effective Moments of Inertia. Dynamic

Equations for Multiple-Degree-of-Freedom Robots. Static Force Analysis of Robots. Transformation of Forces and Moments between Coordinate Frames. Design Project. Trajectory Planning. Path vs. Trajectory. Joint Space vs. Cartesian-Space. Basics of Trajectory Planning. Joint space trajectory planning, Cartesian space trajectories. Application of Robotic in BME. Introduction to medical robotics. Mechanisms for medical robots. Sensing for medical robots. Actuators for medical robots. Controls for medical robots, Interfaces for medical robots.

*Recommended Books:*

1. *Peter Mckinnon, Robotics: Everything You Need to Know About Robotics from Beginner to Expert, ed. I$^{st}$ , CreateSpace Independent Publishing Platform, 2016*
2. *Peter Corke, Robotics Vision and Control: Fundamental Algorithms in MATLAB, ed. 2$^{nd}$, Springer, 2017*
3. *Siciliano et al., Handbook of Robotics, ed. 2$^{nd}$, Springer, 2016*

*BME-415_* **Biofluid Mechanics: (2+1)**

*Course Outline:*

Fluid Mechanics Basics, Term and Definition, Scope of fluid mechanics, Scope of Bio fluid Mechanics, Fundamental Fluid Mechanics Equations, Fluid as a continuum, Elemental Stress and Pressure, Viscosity, Fluid Motions, Two Phase flows, Fluid Structure interaction, Introduction to Turbulent flow the relation the Relationship of Turbulence to Biological Systems. Conservation Laws, Fluid Statics Equations, Buoyancy, Conservation of Mass, Conservation of Momentum, Momentum Equation with Acceleration, Laws of thermodynamics, The Navier Stokes Equations, Bernoulli Equations. Microcirculation and Microcirculation, Heart Valve Function, Arterial and Venous System, Pressure, Flow, and Resistance of blood flow system, Windkessel Model for Blood Flow, Flow separation at Bifurcations and at walls, Flow through Tapering and Curved Channels, Pulsatile Flow and Turbulence, Local control of Blood flow, Pressure Distribution Throughout the Microvascular system, Velocity Distribution Throughout the Microvascular system, Hematocrit/Fahraeus–Lindquist Effect/Fahraeus Effect, Plug Flow in Capillaries, Heart Valve Movement, Heart Function analysis. Biosystems Heat Transfer, Microscale Heat Transfer, Bioheat transfer, Application of Magnetic Field in Hyperthermia, Application of Ultrasonic wave.

*Recommended Books:*

1. *David Rubenstein, Biofluid Mechanics: An Introduction to Fluid Mechanics, Microcirculation, Microcirculation, ed. 2$^{nd}$, Academic Press, 2015*
2. *Majid ghassemi, Nano and Bio Heat Transfer and fluid flow, ed. 1$^{st}$, Academic Press, 2017.*

*BME-416_* **Bioinformatics: (3+0)**

*Course Outline:*

History and evolution of bioinformatics, Introduction to databases (Database types, Database formats, DNA databases, European Molecular Biology Laboratory (EMBL), Genomics, Transcriptomics, Computational proteomics. Pairwise Sequence Alignment, Evolutionary Basis,

Sequence Homology versus Sequence Similarity, Sequence Similarity versus Sequence Identity. Database Similarity Searching, Unique Requirements of Database Searching, Heuristic Database Searching, Basic Local Alignment Search Tool (BLAST), FASTA, Comparison of FASTA and BLAST. GenBank and DNA Data base of Japan (DDBJ), Protein information Resource (PIR) formats, Protein. Sequence (databases, SwissProt, UniProt, UniProtKB/TrEMBL), Structural databases (Protein Databank (PDB), Structural classification of Proteins (SCOP) database, Class, Architecture, Topology, Homology (CATH) database).

*Recommended Books:*

1. *Arthur M. Lesk, Introduction to Bioinformatics, ed. 4th, Oxford University Press, 2014.*
2. *Jonathan Pevsner, Bioinformatics and Functional Genomics, ed. 2nd, Wiley, 2009.*

*CS-361_* **Artificial Intelligence: (3+1)**

*Course Outline:*

Introduction to Artificial Intelligence, Introduction to representations, techniques and architectures used to build applied systems and to account for intelligence from a computational point of view. This course also explores application of rule chaining, heuristic search, logic, constraint propagation, constrained search, and other problem-solving paradigms. In addition, it covers applications of decision trees, KNN, Naïve Bayes Classification, neural nets, and other learning paradigms.

*Recommended Books:*

1. *Russell S. & Norvig P., Artificial intelligence: A Modern Approach, ed. 3rd, Pearson, 2016.*
2. *Luger G.F., Artificial Intelligence: Structures and Strategies for Complex Problem Solving, ed. 6th, Pearson, 2008.*

*BME-418_* **Hospital Information Management Systems: (3+0)**

*Course Outline:*

Introduction, Basics of Information Systems, Rudiments of Healthcare Information Management System, HIS, Now and future. Data standards, Handling and Processing, Data representation, Storage Tiers, Data Structure, Flow Charts and Work Process Flow Diagrams, Electronic Health Records (HERs), Pros & Cons of Paper medical records, Functions and Benefits of EHRs. Subsystems of HIS, Health Information Systems in Clinical Settings, Laboratory Information Systems, Radiology Information Systems, Clinical Decision Support Systems (CDSS), Healthcare Financial Management. Network and Communication, Medical device networking, DICOM, HL7 standards.

*Recommended Books:*

1. *Reinhold Haux, Strategic Information Management in Hospitals: An Introduction to Hospital, ed. 1st, Springer, 2004.*
2. *Florian Leiner, Medical Data Management: A Practical Guide, ed. 1st Springer, 2003.*

*BME-419_* **Medical Device Quality Systems and Standards: (3+0)**

*Course Outline:*

Quality Management System, Term and Definition, General Requirements, Quality Manual, Control of Documents, Controls of Records. Management Responsibility and Resource, Management commitment Requirement, Planning, Responsibility, Authority, and Communication. Provision of Resources, Infrastructure and work environments. Product Realization, Planning of Product Realization, Customer Related Processes, Design and Development, Purchasing, Production and Service Provision, Validation of Processes of Production, Identification and Traceability, Control of Monitoring and Measuring Device.

*Recommended Books:*

1. *Itay Abuhav , A Complete Guide to Quality Management in the Medical Device Industry, CRC Press, ed. 2nd, 2018*

*BME-420_* **Medical Image Processing: (2+1)**

*Course outline:*

Digital Image Fundamental, Image file formats, Elements of Visual Perception, Image Sampling and Quantization, An Introduction to the Mathematical Tools Used in Digital Image Processing. Intensity Transformations and Spatial Filtering, Basic Intensity Transformation Functions, Histogram Processing, Fundamentals of Spatial Filtering, Smoothing Spatial Filters, Sharpening Spatial Filters. Filtering in the Frequency Domain, Review of Concept about Fourier in 1D, Fourier Functions of Two Variable, The Basics of Filtering in the Frequency Domain, Image Smoothing Using Frequency Domain Filters. Image Sharpening Using Frequency Domain Filters. Image Restoration and Reconstruction, Noise Models, Restoration in the Presence of Noise Only Spatial Filtering, Periodic Noise Reduction by Frequency Domain Filtering, Inverse Filtering, Least Squares Filtering, GM filtering, Image Reconstruction from Projections. Image Segmentation, Point, Line, and Edge Detection, Thresholding, Region-Based Segmentation, Segmentation Using Morphological Watersheds, The Use of Motion in Segmentation. Image Compression, Compression Standards, Some Basic Compression Methods (Huffman Coding, Golomb Coding).

*Recommended Books:*

1. *Rafael C. Gonzalez., Digital Image Processing, ed. 4th, Prentice Hall, 2017.*
2. *Geoff Dougherty, Digital Image Processing for Medical Applications, ed. 1st, Cambridge University Press, 2018.*

*BME-423_* **Telemedicine Systems: (2+1)**

*Course Outline:*

Origins and Development of Telemedicine, Overview of e-Health, Telehealth and Telemedicine, Technological & non-technological drivers, Benefits and limitations of telemedicine, Telemedicine in developed & underdeveloped nations. Technologies of Telemedicine Systems, Types of information & transmission, Tele-Consultation and Telemonitoring, Types of Wireless Networks, Communication Protocols, shared variables and network streaming. Telemedicine Applications, Tele-Radiology, Tele-Dermatology, Tele-Pathology, Tele-cardiology, Tele-Ophthalmology, Tele-Surgery, Tele-psychiatry, Tele-dentistry, Disaster Management. Development and Delivery of Telemedicine Services, The Strategic Context of Service Development: USA, Australia, the UK and Malaysia, The Evaluation of Pilot Studies. Ethical and Legal Aspects of Telemedicine, Confidentiality, Patient Rights and Consent, Data Protection and Security, Telemedical Malpractice, Intellectual Property Rights. Future Trends in Healthcare Technology, Prognostics in Telemedicine, The Aging Population: Home Care for the Elderly, Smart Home Assistive Technologies, Clothing Technology and Healthcare, Haptic Sensing for Practitioners

*Recommended Books:*


1. *Bernard Fong et al. , Telemedicine Technology: Information Technologies in Medicine and Telehealth , ed. 2nd , John Wiley & Sons, 2011*
2. *A. C Norris, Essentials of Telemedicine & Telecare, ed. 1st, Wiley, 2008.*
3. *Marlene Maheu et al., E-Health, Telehealth & Telemedicine: A guide to startup and success,ed. 1st, Jossey-Bass, 2001*


*BME-421_* **Biophysics: (2+1)**

*Course Outline:*

Optics, Optics of Vision: Quantum Nature of Vision, Visual Sensation, Bipolar Cells and the generation of Contrast Coding, Visual Transduction, Parallel processing, Receptive fields, Ocular dominance. Biophysics of Hearing, Ear, Electrical activity of ear, Information processing, Coding of intensity information, Impedance properties of ear. Nervous system, Biophysics of Neural Spike, Information theory and Memory, Nervous system. Structural Biophysics, Conformational analysis of proteins /polysaccharides based on potential energy calculations. Molecular modeling of nucleic acids. Membrane Biophysics, Mechanisms, Simple Diffusion and Electro-diffusion, Electrochemical Equilibrium Non-Equilibrium Situations: Ion Fluxes, Passive Transport through Membranes, Electrical Measurements, dialysis equilibrium, active ion transport, energetics of ion transport, estimation of membrane potential from equilibrium concentration. Bioenergetics, Thermodynamic principles: First law (energy, enthalpy), Second law of Thermodynamics, Free energy, standard physical free energy, standard biological free energy, determination of the free energy from equilibrium constant and EMF measurements, Thermodynamics of phosphate compounds (phosphate transfer reactions), Role of ATP for biological energy transfer, Thermodynamics of life. Energy Pathways, Coupled Reactions, Group Transfer Potential, Role of Pyridine Nucleotides, Energy Conversion Pathways, Chemi-osmotic theory. Muscle biophysics, Skeletal muscle structure, muscle types, muscle ultrastructure, neuromuscular junction, Excitation-Contraction coupling, Skeletal muscle mechanics, muscle energetics: heat production, energy metabolism. Muscle energetics, phosphorylation of ADP by phosphocreatine, anaerobic metabolism, muscle diseases.

Respiratory Biophysics, Neurological control respiratory system, Neural mechanisms, chemical mechanisms, Alternation of blood gases, acid base balance, buffer system, lung diseases.

*Recommended Books:*


1. *V. Pattabhi & N. Gautham, Biophysics, ed. 1st, Springer, 2002.*
2. *K. E. Van Holde , Principles of Physical Biochemistry Book, ed. 2nd , Prentice-Hall, 2005*
3. *Andrew W Wood , Physiology, Biophysics, and Biomedical Engineering : Series in Medical Physics and Biomedical Engineering, , ed. 1st , CRC Press, 2012.*


*BME-425_* **DNA Computing: (3+0)**

*Course Outline:*

Introduction to Biomolecules, Computational biology: Introduction to Bioinformatics. Protein folding and misfolding, Protein Architecture: Sequence of amino acids, protein interaction. Structures, Secondary structure of proteins, Tertiary structure of proteins, Nucleic Acid Structure. DNAs and RNAs, Interactions and conformations of DNAs. Interactions and conformations of RNA. Computer Simulations of biomolecules, Classical versus quantum descriptions, Statistical mechanics of biomolecules (e.g., canonical ensemble, ergodicity), Modeling interaction in protein (Bond-length and bond-angle potentials), Molecular Dynamics Simulations. Numerical integration of Newton equations of motion, Algorithms.

*Recommended Books:*


1. *D. Frankel and B. Smit, Understanding Molecular Simulations: From Algorithms to Applications, ed. 2nd, Academic Press, 2001.*
2. *T. E. Creighton, Proteins, ed. 2nd, W.H. Freeman, 1993*


*BME-316_* **Drug Delivery Systems: (3+0)**

*Course Outline:*

Diffusion and Drug Dispersion, Equations for the diffusive flux (Fick's law), Equations of mass conservation (Fick's second law), Solutions to the diffusion equation with no solute elimination or generation, Solutions to the diffusion equation with solute binding and elimination, Applications. Diffusion in Biological Systems, Measurement of diffusion coefficients, Diffusion in water, Diffusion in polymer solutions and gels, Diffusion in the extracellular space, Diffusion with binding in tissues, Diffusion within cells, Diffusion and reaction. Drug Permeation through Biological Barriers, Mobility of lipids and proteins in the membrane, Permeation through lipid membranes, Permeation through porous membranes, Permeation is enhanced by membrane proteins, Permeation through cell layers. Drug Transport by Fluid Motion, Blood movement in the circulatory system, Interstitial fluid movement, Fluid movement in the lymphatic circulation, Fluid movement in the brain. Drug Delivery Systems, Reservoir and transdermal delivery systems, Matrix delivery systems, Hydrogel delivery systems, Degradable delivery systems, Particulate delivery systems, Responsive delivery system. Case Studies in Drug Delivery,

Controlled delivery of systemic therapy, Implants for local drug delivery, Topically applied devices for controlled release, Ethical issues in Drug Delivery Systems.

*Recommended Book:*

1. *W. Mark Saltzman , Drug Delivery: Engineering Principles for Drug Therapy, ed. 1st, Oxford University Press, 2001*

*BME-444_* **Genetic Engineering: (3+0)**

*Course Outline:*

The basis of genetic engineering, the structure of DNA and RNA, Gene organization, Gene expression, Genes and genomes, Isolation of DNA and RNA, DNA sequencing, Restriction enzymes -- cutting DNA, DNA modifying enzymes, DNA ligase - joining DNA molecules. The methodology of gene manipulation, Host cells and vectors, Plasmid vectors, Bacteriophage vectors, Getting DNA into cells. Cloning strategies, cloning from mRNA, Cloning from genomic DNA, Advanced cloning strategies. The polymerase chain reaction, The methodology of the PCR, PCR techniques, Processing of PCR products. Medical and forensic applications of gene manipulation, Diagnosis and characterization of medical conditions, Treatment using rDNA technology -- gene therapy, RNA interference, DNA profiling.

*Recommended Books:*

1. *Desmond S. T. Nicholl, An Introduction to Genetic Engineering, ed. 3rd Cambridge University Press, 2012.*
2. *James D. Watson, Recombinant DNA: Genes and Genomes - A Short Course, ed. 3rd Cold Spring Harbor Laboratory Press, 2006.*

*BME-432_* **Neuroscience and Neural Networks: (3+0)**

*Course Outline:*

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. Neuronal Circuits, Neuronal circuit in emotional control, Neuronal circuit in reward and addiction, Neuronal regulation of stress. 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, Functions in the brain, Pain pathways in brain, Role of excitatory neurotransmitter in learning and memory, Diseases associated with the malfunctioning of these neurotransmitters, Neuronal degeneration. Catecholamines, Functions in the brain, Diseases associated with the malfunctioning. Neural basis of behavioral plasticity, Human and animal memory, Cellular mechanisms of neural plasticity. Neuroendocrine and motivational systems, Endocrine systems, Feeding behavior, Stress. Diseases of the nervous system, Addiction, Depression, Schizophrenia, Epilepsy, Alzheimer, Parkinson, Prion, Motor Neuron Disease.

*Recommended Books:*

1. *Darakhshan Haleem, Neurochemistry, Neuropharmacology and Behavior,ed.1st, VDM Verlag Dr. Müller, 2010.*
2. *Mark F. Bear, Barry W. Connors and Michael A. Paradiso, Neuroscience: Exploring the brain, ed. 3rd , Lippincott Williams and Wilkins,2006*

*BME-426_* **Regenerative Medicine: (3+0)**

*Course outline:*

Introduction to Regenerative medicine, Stem cell basics, Mechanism of cell regeneration. Therapeutic use of stem cells, Bioprinting, Histology, Gene therapy, Cloning. Nanomaterials for tissue regeneration, Nanoceramics, Polymers, "Smart" bioactive orthopedic implants, Metals. Case studies and article reviews

*Recommended Books:*

1. *Jamie Davies, Tissue Regeneration - From Basic Biology to Clinical Application ed.1st, BoD – Books on Demand, 2012.*
2. *Daniel Eberli, Cells and Biomaterials in Regenerative Medicine, ed.1st, BoD – Books on Demand, 2014*

*BME-427_* **Tissue Engineering: (3+0)**

*Course outline:*

Tissue Engineering Brief historical overview, Current applications and potential, Tissue engineering as an industry, Tissue types and reoccurring structures, Properties of tissues, Components of tissues: cells and the extracellular matrix (ECM), Sources (autograft, allograft, xenograft, stem cell), selection and potential manipulation, compatibility (immunosuppression, immune-isolation, genetic engineering) and the foreign body reaction, Cell culture techniques Cell sources, selection, challenges and potential manipulation. Biomaterials used in tissue engineering. Scaffolds for tissue engineering, In vitro and in vivo testing, Modifications for compatibility and eliciting specific cells, 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. *Bernhard O. Palsson and Sangeeta N. Bhatia, Tissue Engineering, ed.1st , Pearson Prentice Hall,2004.*
2. *Jos Vander Sloten (Editor), Computer Technology in Biomaterials Science and Engineering (Biomaterials Science & Engineering), ed.1st Wiley, 2000.*

*BME-317_* **Computational Fluid Dynamics: (3+0)**

*Course Outline:*

Biofluids, Blood Vessels and Respiratory System Walls, Introduction, Blood Components, Blood Plasma, Blood Cells, Blood Rheology, Blood Constitutive Models, Other Biofluids, Blood Vessels, Morphology, Human Airway Walls. Governing Equations, Introduction, Incompressible Flow Equations, Newtonian flow, Inviscid Flow, Boundary Layer Flow, Generalized Newtonian Fluids, Viscoelastic Fluids, Turbulence, Time averaging, Reynolds Averaged Navier-Stokes Equations (RANS), Incompressible Solid, Small Strain Approximation, Viscoelastic Solids. Analytical Forms, Introduction, Steady Flow in Rigid Tubes, Unsteady Flow in Rigid Tubes, Unsteady Flow in Distensible Tubes. Computational Methods, Introduction, Spatial Discretization, Finite Difference Method (FDM), Finite Volume Method (FVM), Finite Element Method, Boundary Conditions, Temporal Discretization, Explicit Methods, Semi-implicit Methods, Fully- Implicit Methods, Some Numerical Algorithms, Convection and Convection-diffusion equations. Numerical Modelling of Wave Propagation, Introduction, One-Dimensional Equations, The Characteristic System, Boundary Conditions, Solution Methods, Global Taylor-Galerkin Method, Locally Conservative Taylor-Galerkin Method. Three Dimensional Problems, Introduction, Navier-Stokes Equations, Numerical Scheme, Cardiovascular Problems, Flow through a Carotid Bifurcation, Flow through a Human Aorta, Human Airways, A model human airway problem, Inhalation studies.

*Recommended Books:*

1. *J.Y. Tu, G.H. Yeoh, and C. Liu, Computational Fluid Dynamics: A Practical Approach, ed.2nd, Butterworth-Heinemann, 2012.*
2. *H.K. Versteeg and W. Malalasekera, An introduction to Computational Fluid Dynamics. The Finite Volume Method, ed.2nd, Pearson Education India, 2007*

*BME-428_* **Nano-Biotechnology: (3+0)**

*Course Outline:*

The world of small dimensions, Nanoscale Properties (Electrical, Optical, Chemical). Nanoscale visualization techniques, Electron microscopy (TEM, SEM, Cryo-SEM), Scanning probe microscopy (AFM, STM), Diffraction techniques (XRD, synchrotron). Bionanomaterials, Biological building blocks, Bio-nanostructures (nanofibers, nanotubes, nanocellulose). Biological nanomachines, Ribosomes, Photosynthesis systems, Bio-nanomotors. Engineered Nanomaterials, Carbon nanomaterials (fullerenes, graphene, nanotubes, nanofibers), Metal nanoparticles (synthesis, properties and applications), Magnetic nanoparticles (synthesis, properties and applications), Quantum dots, liquid crystals, Nano-porous materials (metallic, zeolite, MOFs). Microfabrication methods (photolithography, soft lithography, replication). Nanofabrication methods (Top-Down approaches). Nanotechnology by self-assembly: (Bottom-Up approach): Principles, thermodynamics, interactions, properties, Supramolecular self-assembly, Protein nanotechnology, DNA nanotechnology. Microfluidics, Surface tension, Capillarity, Reynolds number, Diffusion, Viscosity. Nano-fluidis, Nanopores and nanocapillaries, Debye length. Diffusion in solid phase and drug delivery,

Biological and medical microdevices, Lab on chips, Organ-on chips. Biosensors, Fabrication, Functionalization, Applications. Nanotechnology safety and the environment. Impact of nanotechnology on society and industry.

*Recommended Books:*

1. *Brydson, R. M and Hammond, C., Generic Methodologies for Nanotechnology: Classification and Fabrication. In Nanoscale Science and Technology, ed.1st, John Wiley & Sons, Ltd, 2005.*
2. *Leggett, G. J and Jones, R. A. L., Bio-nanotechnology. In Nanoscale Science and Technology, ed.1st, John Wiley & Sons, Ltd,2005.*
3. *Gibbs, M. R. J., Nanomagnetic Materials and Devices. In Nanoscale Science and Technology, ed.1st, John Wiley & Sons, Ltd,2005.*

*BME-429_* **Medical Device Regulatory Affairs: (3+0)**

*Course Outline:*

Introduction to regulatory affairs, The role of RA, Introduction to major global reference regulations and harmonization's, Overview of regulatory environment in major Asian reference countries, Future trends in regulatory development. Pre-market requirements, Background, Classifications, GMP, Conformity assessment. Advanced products, Combination products. Medical Device Errors, Human Factors, Electronic Health Records. Investigational Device Exemptions, HDEs. Medical Device 510(k). Pre-Market Approval (PMA) submissions. de novo review and Product Development Protocol. FDA Enforcement. FDA Postmarked Transformation. Medicare Reimbursement. FDA and the Food and Drug laws.

*Recommended Books:*

1. *John J. Tobin and Gary Walsh, Medical Product Regulatory Affairs: Pharmaceuticals, Diagnostics, Medical Devices, ed.1st, John Wiley & Sons, 2011.*
2. *Jack Wong and Raymond Tong Kaiyu, Handbook of Medical Device Regulatory Affairs in Asia, ed.1st, CRC Press, 2013.*

*EE-439_* **Introduction to Machine Learning: (3+0)**

*Course Outline:*

The goal of this course is to introduce the undergraduate students to the field of machine learning. The major topics we will cover include supervised learning (e.g. classification and regression), unsupervised learning (e.g. principle component analysis and K-means, EM algorithms). Students will also design and analyze real-world machine learning applications as part of assignments and course project.

*Recommended Books:*

1. *Peter Flack, "Machine Learning: The art and science of Algorithms that makes sense of data", ed.1st, Cambridge University Press, 2012.*

*BME-311_* **Biomedical Signal Processing: (2+1)**

*Course Outline:*

Introduction to Digital Signal Processing, Analog-to-Digital& Digital-to-Analog Conversion, Digital Signals, Systems, and Difference Equations, Realizations of Digital Systems. Time domain Analysis, Digital Convolution, Auto and Cross Correlation. Discrete System Stability, The z-Transforms, Transfer function, pole zero plot, and System Stability. Discrete Time Fourier Transform, Frequency response of discrete system, Frequency spectra of discrete signals, Discrete Fourier Analysis and Periodic Signal Spectrum, Fast Fourier transform (FFT). Finite Impulse Response Filter Design, FIR filter design using window method. Infinite Impulse Response Filter Design, IIR filter design using Bilinear Transformation Method, IIR filter design using Pole-Zero placement, and Impulse Invariance methods. Biomedical Applications, Detection of Events: ECG rhythm analysis, Maternal Interference in Fetal ECG, EEG wave-shape and wave-complexity: Analysis of event related potentials, coherence analysis, detection of EEG rhythms, PPG wave analysis, Sound wave analysis, EMG Processing.

*Recommended Books:*


1. *Ranagaraj M. Rangayyan, Biomedical Signal Analysis, ed.2nd, John Wiley & Sons, 2015.*
2. *Fabian J, Theis and Anke Meyer, Biomedical Signal Analysis: Contemporary methods and Applications, ed.2nd, The MIT Press Cambridge, Massachusetts,2010.*
3. *Li Tan, Digital Signal Processing: Fundamentals and Applications, ed.2nd, Academic Press, 2013.*

## Course Outlines of Management Electives

*MGT-211*: **Principles of Management (3+0)** ← Proposed Course Description by the Institute of Business Administration & Management

*Course Outline:*

This is an introductory course about the management of organizations. Topics covered include principles of management that have general applicability to all types of enterprises, basic management philosophy and decision making, principles involved in planning, organizing, leading, and controlling and recent concepts in management. This course will also cover the basic managerial functions of planning, organizing, leading, and controlling. Evolution and best practices that are being used in today's modern era will also be learnt.

*Recommended Books:*

1. *Stephen P. Robbins and Mary A. Coulter, Management, ed. 12th, Pearson, 2013*

*MGT-310*: **Production and Operations Management (3+0)** ← Proposed Course Description by the Institute of Business Administration & Management

*Course Outline:*

This course is designed to provide the students with an understanding of Operations Management and its application in both manufacturing and service organizations. The course will analyze operations from both the strategic and operational perspectives and highlight the competitive advantages that operations can provide to maximize the profit of the organization. This course will help students to analyze a production or operations situation by applying the OM techniques.

*Recommended Books:*

1. *Engineering Economic Analysis by Donald G. Newnan, Jerome P. Lavelle, Ted G. Eschenbach, ed. 12th Oxford Univ. Press, 2014.*

*MGT-313*: **Total Quality Management (3+0)** ← Proposed Course Description by the Institute of Business Administration & Management

*Course Outline:*

This course is designed to provide in depth Knowledge of the Total Quality Management (TQM) and its effectiveness in Pakistani organizations to improve productivity and efficiency. It presents several TQM frameworks, concepts, and quality improvement tools necessary for implementing the quality culture that characterizes world-class organizations.

*Recommended Books:*

1. *James R. Evans and William M. Lindsay, Management and Control of Quality and Excellence, ed. 4th, South-Western College, 1998.*

*MGT-410*: **Project Management (3+0)** ← Proposed Course Description by the Institute of Business Administration & Management

*Course Outline:*

This course is designed to provide the students with an understanding of project management and its application in real life projects. It presents several project managements concepts and techniques necessary for successful implementation of projects. The students will be able to describe project management and its importance in various projects, develop necessary analytical skills to successfully select, design, implement, control, and terminate projects of varying complexities, handle variety of projects and ensure its successful implementation.

*Recommended Books:*

1. *Clifford F. Gray and Erik W. Larson, Project Management: The Managerial Process, ed. 3rd, McGraw-Hill/Irwin, 2005.*
2. *Project Management Institute, A Guide to the Project Management Body of Knowledge, ed. 5th, Project Management Institute, 2013.*

*MGT-414*: **Entrepreneurship and Business Management (3+0)** ← Proposed Course Description by EED

*Course Outline:*

Topics covered include: Fundamental principles of mental life and human behavior, Significance of psychology in human relationships and self-understanding, evolutionary psychology, neuropsychology, biological psychology, positive psychology, applied psychology, careers, and multiculturalism and diversity.

*Recommended Books:*

1. *Norman M. Scarborough and Jeffrey R. Cornwall, Entrepreneurship and Effective Small Business Management, ed. 11th, Prentice Hall, 2014.*
2. *Norman M. Scarborough, Essentials of Entrepreneurship and Small Business Management, ed.7th, Prentice Hall, 2015.*

*MGT-460*: **Engineering Economics (3+0)**

*Course Outline:*

The course focuses on economic and cost analysis of engineering projects, giving insights on modern techniques and methods used on economic feasibility studies relating to design and implementation of engineering projects. The basic purpose of the course is to provide sound understanding of financial and economic decision making for engineers, with an emphasis on problem solving, life-cycle costs, and the time value of money.

*Recommended Books:*

1. *Donald G. Newnan, Jerome P. Lavelle and Ted G. Eschenbach, Engineering Economic Analysis, ed.12$^{th}$, Oxford Univ. Press, 2014.*