# M. TECH – BIO-MEDICAL ENGINEERING

## DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

The aim of the post-graduate program in Biomedical Engineering is to integrate technology with the medical sciences in such a manner that the synergistic relationship between them can help evolve a better system for medical diagnosis, treatment, research and support systems. It is envisaged that at the end of the program, the student would be in a position to understand the fundamental biological and engineering processes involved as well as to develop creative ideas for the early detection and identification of various biological signals. It is also expected that the student of the program would be able to come up with algorithms for the successful and objective interpretation of biological data. The course deals with biomedical electronics, the quantitative and analytical skills required to interpret the data acquired and the processing of medical data including imaging and enhancement techniques. It is intended to equip the engineer with the skills, knowledge and jargon required to interact knowledgeably with medical practitioners so that both professions may benefit. It goes without saying that the program is interdisciplinary, drawing content from a variety of areas like chemistry, medicine, physics, electronics and mechanical engineering, to name a few.

Medical practice has become highly sophisticated, relying heavily on machines, for diagnosis and support. Modern hospitals therefore, require competent biomedical engineers, who can help the medical personnel, communicate with the highly complex equipment and make sense of the bewildering variety of information provided by them. Biomedical engineers are also in demand with equipment manufacturers, who require experts who are well versed with both the engineering and medical aspects of their equipment. Moreover, with the increase in automation and computerization of medical diagnosis and treatment, biomedical engineering offers ample scope for research in diverse areas like instrumentation, signal and image processing, biomaterials and biomechanics. As such, a student of the post-graduate program in biomedical engineering can expect to have bright career prospects, be it in the industry, academia or research. Amrita University, with its world-class facilities, multi-disciplinary programs, highly qualified, diverse and motivated faculty, is ideally equipped to offer an advanced program in this cutting-edge area of technology.

It is expected that at the end of the program, the student would be equipped with the knowledge and the skills required to become a truly world-class biomedical engineer, ready to embark on a career in either the industry or to undertake independent research.

# CURRICULUM

## First Semester

| Course Code | Type | Course | L T P | Cr |
|---|---|---|---|---|
| 16BM601 | FC | Anatomy and Physiology | 3 0 0 | 3 |
| 16BM602 | FC | Biomedical Signal Analysis | 3 0 1 | 4 |
| 16BM611 | SC | Biomedical Instrumentation | 4 0 0 | 4 |
| 16BM612 | SC | Embedded Systems for Biomedical Applications | 1 0 2 | 3 |
| 16BM613 | SC | Biomaterials | 3 0 0 | 3 |
| 16BM661 | SC | Biomedical Instrumentation Laboratory | 0 0 1 | 1 |
| 16HU601 | HU | Cultural Education* | | P/F |
| | | | Credits | **18** |

*Non-Credit Course

## Second Semester

| Course Code | Type | Course | L T P | Cr |
|---|---|---|---|---|
| 16BM621 | SC | Research Methodology and Medical Ethics | 1 0 0 | 1 |
| 16BM622 | SC | Biomedical Image Processing | 3 0 1 | 4 |
| 16BM623 | SC | Biosensors | 3 0 0 | 3 |
| 16BM624 | SC | Biomechanics | 3 0 0 | 3 |
| | E | Elective I | 3 0 0 | 3 |
| | E | Elective II | 3 0 0 | 3 |
| 16EN600 | HU | Technical Writing* | | P/F |
| | | | Credits | **17** |

*Non-Credit Course

## Third Semester

| Course Code | Type | Course | L T P | Cr |
|---|---|---|---|---|
| | E | Elective III | 3 0 0 | 3 |
| 16BM691 | SC | Internship | | 2 |
| 16BM662 | SC | Open / Live-in Labs | | 1 |
| 16BM797 | P | Prototyping of Biomedical Sub-systems | | 3 |
| 16BM798 | P | Dissertation | | 8 |
| | | | Credits | **17** |

## Fourth Semester

| Course Code | Type | Course | L T P | Cr |
|---|---|---|---|---|
| 16BM799 | P | Dissertation | | 14 |
| | | | Credits | **14** |

**Total Credits: 66**

# List of Courses

## Foundation Core

| Course Code | Course | L T P | Cr |
|---|---|---|---|
| 16BM601 | Anatomy and Physiology | 3 0 0 | 3 |
| 16BM602 | Biomedical Signal Analysis | 3 0 1 | 4 |

## Subject Core

| Course Code | Course | L T P | Cr |
|---|---|---|---|
| 16BM611 | Biomedical Instrumentation | 4 0 0 | 4 |
| 16BM612 | Embedded Systems for Biomedical Applications | 1 0 2 | 3 |
| 16BM613 | Biomaterials | 3 0 0 | 3 |
| 16BM621 | Research Methodology and Medical Ethics | 1 0 0 | 1 |
| 16BM622 | Biomedical Image Processing | 3 0 1 | 4 |
| 16BM623 | Biosensors | 3 0 0 | 3 |
| 16BM624 | Bio Mechanics | 3 0 0 | 3 |
| 16BM661 | Biomedical Instrumentation Laboratory | 0 0 1 | 1 |
| 16BM662 | Open / Live-in Labs | | 1 |
| 16BM691 | Internship | | 2 |

## Elective Subjects

| Course Code | Course | L T P | Cr |
|---|---|---|---|
| 16BM750 | Biophotonics | 3 0 0 | 3 |
| 16BM751 | Diagnostic and Therapeutic Equipment | 3 0 0 | 3 |
| 16BM752 | Nanomaterials for Biomedical Applications | 3 0 0 | 3 |
| 16BM753 | Drug Designing and Delivery Systems | 3 0 0 | 3 |
| 16BM754 | Advanced Signal Processing | 3 0 0 | 3 |
| 16BM755 | Tissue Engineering | 3 0 0 | 3 |
| 16BM756 | Biofluid Mechanics | 3 0 0 | 3 |
| 16BM757 | Biomedical Nanotechnology | 3 0 0 | 3 |
| 16BM758 | Methods for Medical Diagnostics | 3 0 0 | 3 |
| 16BM759 | Laser Instrumentation for Biomedical Applications | 3 0 0 | 3 |
| 16BM760 | Biostatistics | 3 0 0 | 3 |
| 16BM761 | Virtual Instrumentation for Medical Systems | 2 0 1 | 3 |
| 16BM762 | Special Topics in Biomedical Image Processing | 3 0 0 | 3 |
| 16BM763 | Mammogram Image Analysis | 3 0 0 | 3 |
| 16BM764 | Medical Imaging Techniques | 3 0 0 | 3 |
| 16BM765 | Special Topics in Biomedical Instrumentation | 3 0 0 | 3 |
| 16BM766 | BioMEMS | 3 0 0 | 3 |
| 16BM767 | Microwave Biomedical Technology | 3 0 0 | 3 |
| 16BM768 | Special Topics in Biomedical Engineering | | 3 |
| 16BM77x | Certification in relevant, programme-approved NPTEL/GIAN courses | | 3 |

## Project Work

| Course Code | Course | L T P | Cr |
|---|---|---|---|
| 16BM797 | Prototyping of Biomedical Sub-systems | | 3 |
| 16BM798 / 16BM799 | Dissertation | | 22 |

**16BM601 ANATOMY AND PHYSIOLOGY 3-0-0-3**

**Objectives:**

- To understand the function and operation of various organs and systems in the human body
- To understand the origin and nature of various biological signals

Introduction to general human anatomy, nomenclature, surface anatomy, gross location of various systems; Embryology - development of various tissues and formation of organs, anatomy that can go wrong during development - congenital anomalies; Basic physiology at cellular level - functions of each cellular organ; Cell biology, homeostasis, biopotentials, transport mechanisms; Musculosketal system: classification and identification of major bones, joints and muscles, mechanism of action, biomechanics of muscles, action potential; Cardiovascular system: location, position, parts of heart - internal and external anatomy, conducting system of heart, major blood vessels of body, its function and position, blood flow, cardioelectrical activity, regulation of arterial pressure; Respiratory system: location, structure / parts and function of lung, bronchus, pleura; mechanism of respiration, control of breathing; Digestive system (gastrointestinal system): Location, structure / parts, function of stomach, small intestine, large intestine; motility, secretion, absorption; other related structures / function - liver, spleen and pancreas, connecting tubes and vessels; Urinary system - Kidney - location, anatomy, function - filtration, body fluid balance, control of minerals; Genital system - genital organs and functions in male and female, female breast - anatomy and function; Central nervous system & spine - parts of brain, functions of brain at cerebrum, cerebellum midbrain, pons, medulla. Spine: vertebral column, spinal cord, nerves; Head / neck / face system : major parts of face and related bones, and structures, salivary glands, thyroid, lymph nodes, muscles of mastication; Measurement of testing of various parameters that define the function of each organ system – eg. lab tests of blood, urine and other samples; Anatomical/structure evaluation methods correlation including: Radiology and Imaging techniques, Histology, Cytology

**TEXTBOOKS / REFERENCES:**

1. Marieb E and Hoehn K, *Human Anatomy & Physiology*, Tenth Edition, Benjamin Cummings, 2014.
2. Saladin K S, *Human Anatomy*, Fifth Edition, McGraw-Hill, 2011.
3. Guyton A C and Hall J E, *Textbook of Medical Physiology,* Thirteenth Edition, Elsevier Saunders, 2015.
4. Johnson L, *Essential Medical Physiology,* Third Edition, Elsevier Academic Press, 2006.

**Outcomes:**

- Basic understanding of various parts of the human anatomy
- Knowledge of the various physiological systems

**16BM602 BIOMEDICAL SIGNAL ANALYSIS 3-0-1-4**

**Objectives:**

- Knowledge of the application of digital signal processing in the analysis of biomedical signals or biosignals
- To learn about analog-to-digital conversion, sampling, windowing, filtering, spectral analysis, wavelet, time-frequency and classification
- To learn how to calculate, simulate and analyze various biosignals measured from the human body

Signals - Continuous and Discrete - Sampling and quantization - Operations on Signals; Signal Spaces - Representation of signals - Time domain, Frequency domain, Polynomial representation; Vector Spaces - Basis - Dimension - Orthogonality; Linear Transformation and inverse – Fourier Decomposition and Analysis; Power spectrum estimation – Periodiogram –

Eigen decomposition; Multirate signal processing – decimation – interpolation – Polyphase representations – CIC filters; Filtering – IIR Filters - FIR filters – Finite word length effects; Introduction to Biomedical Signals - Concurrent, Coupled, and Correlated Processes – Noise Process - Filtering for Removal of Noise and Artifacts -Event Detection.

**TEXTBOOKS / REFERENCES:**


1. Rangayyan R M, *Biomedical Signal Analysis - A Case-Study Approach*, Second Edition, Wiley -IEEE Press, 2015.
2. Suresh R. Devasahayam , *Signals and Systems in Biomedical Engineering*: Signal Processing and Physiological Systems Modeling, Second Edition, Springer 2013.
3. Moon T K and Stirling W C, *Mathematical Methods and Algorithms for Signal Processing*, Prentice Hall, 2000.
4. Hayes M H, *Statistical Digital Signal Processing and Modelling*, John Wiley and Sons Inc, 2002.


**Outcomes:**

The student will be able to

- Analyze bioelectric signals and measurements using analog-to-digital conversion, sampling, re-sampling and windowing
- Apply cross-correlation and covariance biosignal processing techniques in the analysis of recorded electroencephalographic and electrocardiographic biosignals
- Manage digital filtering, noise reduction, classical and modern spectral analysis, wavelet and time-frequency

**16BM611 BIOMEDICAL INSTRUMENTATION 4-0-0-4**

**Objectives:**

- To understand the nature and origin of various bioelectric signals
- To understand the operation of various building blocks of biomedical circuits
- To understand the operation of different biomedical equipment

Biosignals: Cell potential – Sodium channel, Action potential, Electrocardiograph, EEG / EMG / ERG, Typical Characteristics, Electrodes, Body / Electrode / Instrument interface; Error Analysis: Classification, Propagation of Errors; Operational Amplifiers: Requirements, Differential Pair (BJT), Differential Amplifier; Typical Op-amp (μA 741): Input impedance, Input offset voltage and current, Bias Current; Operational Amplifier Circuits: Inverting Amplifier, Non-inverting amplifier, Current Source, Comparator, Precision Rectifier, Integrator, Phase-Sensitive Detector, Isolation Amplifier, Wein Bridge Oscillator, RC Phase-shift amplifier, Astable Multivibrator, Monostable Multivibrator, Timer – 555, Low-pass Filter, High-pass filter, Band-pass / Band-reject filters, Notch Filter; Instrumentation Amplifier: Characteristics and requirements, Single op-amp, Dual op-amp, Triple op-amp, Linear Gain Control; Medical Systems - Sources of artifacts / consequences, Lithotriptor, Thermograph, ECG machine, Endoscope, Haemodialysis machine, Heart-Lung machine, Pulse Oximeter, De-fibrillator, Holter monitor, Infusion pumps, Sphygmomanometer, Incubators, Cardiac Catheterisation Lab.

**TEXTBOOKS / REFERENCES:**


1. Webster J G, *Medical Instrumentation: Application and Design*, Fourth Edition, Wiley, 1998.
2. Kutz M, *Biomedical Engineering and Design Handbook*, Second Edition, McGraw-Hill, 2009.
3. Bronzino J, *Biomedical Engineering and Instrumentation: Basic Concepts and Applications*, PWS Engineering, 1986.
4. Franco S, *Design with Operational Amplifiers and Analog Integrated Circuits*, Third Edition, McGraw-Hill, 2002.

5. Sedra A and Smith K C, *Microelectronic Circuits*, Seventh Edition, Oxford University Press, 2014.

**Outcomes:**

- Better understanding of bioelectric signals
- Ability to design, analyse and troubleshoot simple biomedical circuits
- Understanding of the operation of biomedical equipment

**16BM612 EMBEDDED SYSTEMS FOR BIOMEDICAL APPLICATIONS 1-0-2-3**

**Objectives:**

- To introduce the basic concepts of Embedded Systems
- To provide a platform to understand the concepts of Real Time Operating Systems
- To learn and practice Real Time Embedded System Development

Introduction to Embedded Systems, Examples of embedded system, their characteristics and their typical hardware components, Software Embedded into a system embedded software architecture , Processor and Memory organization Structural Units in a processor, Processor Selection for an embedded system, complex system design and processors, design process, formalization of system design, classification of embedded system, skills required for embedded system designer, Memory devices, Memory selection for an embedded system, Allocation of Memory to program segments and blocks and memory map of a system, Direct Memory access, Interfacing processor, memories and I/O devices; Devices and Buses for Device networks: I/O devices, Timer and counting devices, Serial Communication devices using the 'I2C','CAN' and Advanced I/O Buses between the networked multiple Devices, host system or computer parallel communication between the networked I/O Multiple Devices using the PCI, PCI-X and advanced buses; Device Drivers and Interrupts Servicing Mechanism: Device drivers, Parallel port device drivers in a system, serial port device Drivers in a system, device drivers for internal programmable timing devices, Interrupt servicing (handling) mechanism, Deadline and Interrupt Latency; Program Modeling concepts in Single and Multiprocessor: Modeling process for software analysis before implementation, models for event control programs and multiprocessors systems, software development process lifecycle, analysis, design and implementation, software testing, project management and maintenance; Real Time Operating System and inter-process communications: Concepts of RTOS, I/O subsystems, network operating systems, real time and embedded operating systems, interrupt routines in RTOS, task scheduling models, multitasking, shared data problems, inter-process communication, starvation and dead lock.

**TEXTBOOKS / REFERENCES:**

1. Ayala K J, *The 8051 Microcontroller*, Third Edition, Cengage Learning India Pvt. Ltd., 2007.
2. Valvano J W, *Embedded Microcomputer Systems - Real Time Interfacing*, Third Edition, Cengage Learning India Pvt. Ltd., 2012.
3. Vahid F and Givargis T, *Embedded System Design: A Unified Hardware / Software Introduction*, Third Edition, John Wiley and Sons, New Delhi, 2010.

**Outcomes:**

- Students will be able design basic Embedded Systems
- Students will be able to develop Embedded Applications in Embedded C Language
- Students will be able to configure the peripherals in PIC Microcontroller which are required for their application

**16BM613 BIOMATERIALS 3-0-0-3**

**Objectives:**

- Understand the basic concepts of materials structure and properties
- Understand protein adhesion, host responses, and material biocompatibility of biomaterials

- Understand how materials are used for various biomedical applications

Introduction to Biomaterials - Basics of Material Structure, Overviews of Metals, Polymers, Ceramics and Natural Materials used in Biomedical Engineering; Properties and Characterization of Materials; Proteins, Adhesion and Cell Structure, Host Responses, Biocompatibility, Degradation of Biomaterials, Testing of Biomaterials; Applications - Cardiovascular, Orthopedic, Ophthalmologic, Dental Implants, Sutures, Burn Dressings, Adhesives & Sealants, Bioelectrodes, Biomedical Sensors & Biosensors, Tissue Engineering and Scaffolds Product Development And Regulation.

**TEXT BOOKS / REFERENCES:**

1. Ratner B D, Hoffman A S, Schoen F J and Lemons J E, *Biomaterials Science: An Introduction to Materials in Medicine*, Third Edition, Academic Press, 2012.
2. Hill D, *Design Engineering of Biomaterials for Medical Devices*, John Wiley, 1998.
3. Park J B and Lakes R S, *Biomaterials: An Introduction*, Plenum Press, 1992.

**Outcomes:**

- Understanding of materials structure and properties
- Understanding of host responses and biocompatibility
- Familiarity with some biomedical applications of materials

**16BM661 BIOMEDICAL INSTRUMENTATION LABORATORY 0-0-1-1**

Differential Amplifier; Current Sources; Operational amplifiers - Characterisation and Simple Circuits; Instrumentation Amplifiers; Multivibrators and Timers; ECG Pre-amplifier.

**16BM621 RESEARCH METHODOLOGY AND MEDICAL ETHICS 1-0-0-1**

**Objectives:**

- To understand the process of research
- To know how to go about communicating the results of research
- To understand the need for ethical research
- To understand the issues involved in clinical trials and research involving human volunteers

Research Methodology – Selection of project domain – Topic – Literature Survey – Research Process – Research paper – Publication types – Quality Metrics – Impact Factor – Indexing – Citations – Project Proposal – Presentation – Report preparation; Research Ethics – Conflict of interest, Mentoring, Plagiarism, Case Studies and Presentations; Medical Ethics – Moral, legal, social, religious and cultural contexts, Information and Consent, Truthfulness, Voluntariness, Confidentiality, End-of-life ethics, Genetics and Biotechnology, Children and pregnant women, Clinical trials

**TEXTBOOKS / REFERENCES:**

1. Das R and Das P N, *Biomedical Research Methodology: Including Biostatistical Applications*. New Dehi: Jaypee Brothers Medical Publishers, 2011.
2. Kothari C R and Garg G, *Research Methodology: Methods and Techniques*, Third Edition, New Age International, 2014.
3. Singer P and Viens A M, (Eds.), *The Cambridge Textbook of Bioethics*, Cambridge University Press, 2008.
4. Louis G E, *Ethics in Engineering Research and Practice*, University of Virginia, 2010.
5. Shamoo A and Resnik D B, *Responsible Conduct of Research*, Second Edition, Oxford University Press, 2009.

**Outcomes:**

- Understanding of the process involved in research

- Understanding of how to conduct a survey of the literature
- How to make use of relevant tools
- To recognize and understand potential sources of conflict in research
- To recognize the ethical issues involved in conducting research in biomedical engineering

**16BM622 BIOMEDICAL IMAGE PROCESSING 3-0-1-4**

**Objectives:**

- To introduce various imaging modalities for biomedical applications and properties of resulting images
- To introduce basic image processing algorithms
- To learn different feature extraction methods and classification algorithms

Sources of Medical Images - Introduction to X-ray, CT, PET, MRI, and ultrasound images, Properties, Advantages and disadvantages; Image Enhancement - Enhancement in spatial and frequency domains, Applications: Noise reduction in Nuclear Medicine Imaging, Contrast enhancement of mammograms; Morphological Image Processing - Binary and gray-scale morphological operations, Morphological algorithms, Applications: Enhancement of masses in mammograms; Image Segmentation - Global thresholding, Adaptive thresholding, Region growing, Region splitting and merging, Edge detection Applications: Detection of calcifications in mammograms, Detection of the spinal canal; Pattern classification and diagnostics - Feature extraction, Feature selection, Supervised and Unsupervised classification, Bayes classifier, Neural network and Fuzzy classification, Support vector machines, Applications: Classification of breast masses. The course also has a laboratory component where the student will apply the algorithms and techniques learnt, on various biomedical images of interest.

**TEXTBOOKS / REFERENCES:**

1. Meyer-Baese A, *Pattern Recognition in Medical Imaging*, Academic Press, 2003.
2. Dougherty G, *Digital Image Processing for Medical Applications*, Cambridge University Press, 2009.
3. Gonzalez R C and Woods R E, *Digital Image Processing*, Third Edition, Prentice Hall, 2007.
4. Rangayyan R M, *Biomedical Image Analysis*, Fifth Edition, CRC Press, 2005.
5. Deserno T M, *Biomedical Image Processing*, Springer, 2011.
6. Wolfgang Berkfellner, *Applied Medical Image Processing: A Basic Course*, Second Edition, CRC Press, 2014.

**Outcomes:**

- Students will be able to choose appropriate image processing algorithms for different kinds of biomedical images
- Students will be able to perform operations including enhancement and segmentation, on biomedical images
- Students will be able to extract suitable features from biomedical images and employ them for pattern recognition

**16BM623 BIOSENSORS 3-0-0-3**

**Objectives:**

- Understanding of the operation of different biosensors
- Understanding of various characterisation techniques
- Familiarisation of Lab-on-a-Chip concepts

Introduction to biosensor - classification based on the signal transduction and biorecognition element; Enzymatic and non-enzymatic sensors, DNA and protein based sensors - immunosensors; Principle, fabrication and working of optical biosensors - direct and indirect detectors - surface Plasmon-electroluminescence; Electrochemical biosensors: construction and

working of potentiometric, amperometric and impedemetric sensors; Development and applications of piezoelectric sensors. Optical and electrochemical sensors for glucose, vitamins, cholesterol, dopamine, nitric oxide, nitrates, and pesticides; Biochips and electrochemical microarrays - lab-on-a-chip. Biosensing using nanomaterials. Biocompatibility of sensors; PCR Principles - Bioreactors.

**TEXTBOOKS / REFERENCES:**


1. Zhang X, Ju H and Wang J, *Electrochemical Sensors, Biosensors and Their Biomedical Applications*, Academic Press, 2008.
2. Grundler P, *Chemical Sensors – An Introduction for Scientists and Engineers*, Springer-Verlag, 2007.
3. Merkoci A, *Biosensing Using Nanomaterials*, John Wiley & Sons, 2009.
4. Rasooly A and Herold K E (Eds), *Biosensors and Biodetection: Methods and Protocols Volume 503: Optical-Based Detectors*, Springer-Verlag, 2009.
5. Rasooly A and Herold K E (Eds), *Biosensors and Biodetection: Methods and Protocols Volume 504: Electrochemical and Mechanical Detectors, Lateral Flow and Ligands for Biosensors*, Springer-Verlag, 2009.


**Outcomes:**

- Familiarisation with various biosensors
- Understanding of the operation and characterisation of electrochemical sensors for different biomarkers

**16BM624 BIOMECHANICS 3-0-0-3**

**Objectives:**

- To introduce the basic concepts of viscoelasticity, mechanical properties and behaviour of skeletal tissues
- To provide the basic knowledge of linear and angular kinematics and kinetics and instruct how to apply them to gait analysis and sports biomechanics
- To learn the mechanics of skeletal joints and use them to find the unknown forces at the joints for various static and dynamic human activities

Elements of Rheology and principles of continuum mechanics, viscoelasticity, generalized theory of elasticity; Structure, properties and mechanics of soft and hard tissues (bones, cartilage, muscles, tendon and ligaments); Anatomical positions, planes and axes, Segments of human body: segmental parameters, centre of mass and centre of gravity; Biomechanical analysis of human motion: linear and angular kinematics, linear and angular kinetics; Classification of joints, Mechanics of joints in lower and upper extremities, Mechanics of spine; Estimation of muscle forces, joint reaction forces and moments; Computational modeling / design / analysis of artificial joints / implants / prosthesis / orthosis.

**TEXTBOOKS / REFERENCES:**


1. Margareta Nordin and Victor H. Frankel, *Basic Biomechanics of Musculoskeletal System*, Fourth Edition, Lippincott, Williams and Wilkins, 2012.
2. Fung Y C, *Biomechanics: Mechanical Properties of Living Tissues*, Second Edition, Springer-Verlag, 1993, Special Indian Edition by New Age International, 2007.
3. Susan J. Hall, *Basic Biomechanics*, Sixth Edition, McGraw-Hill, 2011.
4. Nihat Ozkaya, Margareta Nordin, David Goldsheyder, Dawn Leger, *Fundamentals of Biomechanics - Equilibrium, Motion, and Deformation*, Third Edition, Springer, 2012.
5. Ming Zhang and Yubo Fan, *Computational Biomechanics of the Musculoskeletal System*, CRC Press, 2014.


**Outcomes:**

- Students will be able to understand the viscoelastic properties and behaviour of biological tissues

- Students will be able to understand the basic structure, function and mechanical properties of basic skeletal tissues
- Students will be able to analyze human body motions and apply to gait analysis, sports biomechanics
- Students will be able to analyze the muscle and joint reaction forces at a skeletal joint for various static and dynamic human activities
- Students will be able to model, design and analyze artificial joints / implants / prosthetics / orthotics

**16EN600 TECHNICAL WRITING P/F**

**Objectives:**

- To understand the importance of technical communication and its different forms
- Familiarisation with different forms of technical communication and their requirements
- Familiarisation with the various requirements and resources for technical writing

Technical terms – Definitions - extended definitions - grammar checks - error detection – punctuation - spelling and number rules - tone and style - pre-writing techniques - Online and offline library resources - citing references - plagiarism - Graphical representation - documentation styles - instruction manuals - information brochures - research papers, proposals - reports (dissertation, project reports etc.) - Oral presentations.

**TEXTBOOKS / REFERENCES:**

1. Hirish H L, *Essential Communication Strategies for Scientists, Engineers and Technology Professionals*, Second Edition, IEEE Press, New York, 2002.
2. Anderson P V, *Technical Communication: A Reader-Centred Approach*, Eighth Edition. Cengage Learning India Pvt. Ltd., New Delhi, Reprint 2010.
3. Strunk Jr. W and White E B, *The Elements of Style*, Alliyan and Bacon, New York, 1999.

**Outcomes:**

- Understanding of the different styles of various technical bodies
- Knowledge of the various tools available for technical writing

**16BM750 BIOPHOTONICS 3-0-0-3**

**Objective:**

- To understand light-tissue interaction and the various techniques /equipment for its study

Introduction; Light-Matter interaction; Rayleigh and Mie Scattering; Spectroscopy - Fluorescence, Raman, CARS, ESS; Ballistic Imaging – Confocal, Non-linear, OCT and Doppler OCT; Radiation transfer and diffusion; Diffuse Optical Tomography; Glucose diagnostics; Optical Tweezers; Photoacoustic Tomography, Photoplethysmography (PPG).

**TEXTBOOKS / REFERENCES:**

1. Prasad P, *Introduction to Biophotonics*, Wiley-Interscience, 2003.
2. Vo-Dinh T, *Biomedical Photonics Handbook*, Second Edition, CRC Press, 2014.
3. Collins J, *Biophotonics: Spectroscopy, Imaging, Sensing, and Manipulation*, Springer, 2011.
4. Popp J and Strehle M, *Biophotonics: Visions for Better Health Care*, Wiley-VCH, 2006.
5. Popp F A, Dualibe C V and Beloussov L V (Eds.), *Integrative Biophysics: Biophotonics*, Kluwer Academic Publishers, 2003.

**Outcomes:**

- Understanding of the characteristics of light-tissue interaction
- Knowledge of the various methods / equipment for studying light-tissue interaction
- Knowledge of the use of optical techniques for measuring certain biomedical parameters

## 16BM751 DIAGNOSTIC AND THERAPEUTIC EQUIPMENT 3-0-0-3

**Objective:**

- Study the various diagnostic and therapeutic equipment used in hospitals / biomedical laboratories

Analytical Instrumentation – UV / Visible Spectrophotometer, Atomic Absorption Spectrophotometer, Mass Spectrophotometer, Automated biochemical Analysis system, Gas Chromatography – Liquid Chromatography, Blood Gas Analyzer, Blood Cell Counter, Auto Analyzer; CO2 incubators, Cryo Centrifuges; Intensive Coronary Care Units - Central Monitoring system, Drug Delivery Systems, Intelligent Drug Delivery, Neurological Instrumentation,Respiratory Care Unit Equipment, Nebulizers, Mechanical Ventilators, CPAP Devices; Advanced Life Support Systems - Cardiac Life Support Equipment, Pediatric Advanced Life support & Neonatal Resuscitation; Operation Theatre Equipment - Surgery Equipment, Electrosurgical Units; Laser Surgery - $CO_2$, Nd YAG, Ruby, Argon, Krypton Lasers; Endoscopy - Types, Rigid, Flexible, Illuminations and Image transmission systems; Laparoscopy; Perfusion Equipment - Anaesthesia, Ventilators, Heart Lung machine, Fumigators; Radio Therapy - Cobalt Unit, Ionization Chambers, Geiger-Muller Counters, Gas proportional counters, Scintillation Counters, Solid State Radiation Detectors, Linear Accelerators

**TEXTBOOKS / REFERENCES:**


1. Khandpur R, *Handbook of Biomedical Instrumentation*, Second Edition, Tata McGraw-Hill, 2003.
2. Bronzino J, *Biomedical Engineering and Instrumentation: Basic Concepts and Applications*, PWS Engineering, 1986.
3. Carr J and Brown J M, *Introduction to Biomedical Equipment Technology*, Fourth Edition, Pearson, 2008.
4. Webster J G, *Encyclopedia of Medical Devices and Instrumentation*, Volume 1, John Wiley and Sons, Inc., 2011.
5. Webster J G, *Medical Instrumentation: Application and Design*, Fourth Edition, Wiley, 2010.


**Outcomes:**

- Knowledge of the function of various diagnostic and therapeutic equipment
- Familiarity with their operation, through hospital visits

## 16BM752 NANOMATERIALS FOR BIOMEDICAL APPLICATIONS 3-0-0-3

**Objectives:**

- To understand the different methods for studying the properties of nanomaterials
- To understand the various methods for characterizing nanomaterials
- To understand the process of nanomaterial synthesis

Introduction to Nanomaterials: Size dependence of properties – Surface to volume ratio and Quantum confinement; Microscopic techniques to study nano structures - SEM, AFM, TEM and STM; Spectroscopic techniques to characterize nanostructures - Raman, XPS, Auger, EDAX; Synthetic approaches: Colloidal, Self-Assembly (Self assembled monolayers-SAMs) and electrostatic self-assembly, electrochemical methods (cathodic and anodic processes), sol-gel, Langmuir-Blodgett (LB) technique, chemical vapour deposition, plasma arcing and ball milling, lithography; Electrical, optical, mechanical, chemical and magnetic properties of nanomaterials; Carbon Clusters: Synthesis, properties and biomedical applications of Fullerenes, Carbon nanotubes and Graphenes. Quantum Dots, wells and wires (metallic and semiconducting) - Preparation, properties and biomedical applications; Dendrimeric structures and their applications; Biofunctionalisation of nanomaterials - Surface Plasmon resonance – Fluorescence Resonance energy transfer (FRET).

**TEXTBOOKS / REFERENCES:**


1. Nabok A, *Organic and Inorganic Nanostructures*, Artech House, Inc., 2005.
2. Ju H, Zhang X and Wang J, *NanoBiosensing, Principles, Development and Application*, Springer, 2011.
3. Mozafari M R (Ed.), *Nanomaterials and Nanosystems for Biomedical Applications*, Springer, 2007.
4. Wang Z L (Ed.), *Characterisation of Nanophase Materials*, Wiley VCH, 2000.


**Outcomes:**

- Understanding of the properties of nanoparticles and their characterisation
- Knowledge of the process of synthesizing nanomaterials
- Knowledge of possible biomedical applications of nanomaterials

**16BM753 DRUG DESIGNING AND DELIVERY SYSTEMS 3-0-0-3**

**Objectives**:

- To understand the basics of drug design
- To understand the different methods for simulating drug molecules and criteria for selecting them
- To understand the fundamentals of drug administration and delivery systems

Introduction - Drug-likeness, Source of drugs, drug-designing strategy, DNA-based drug designing, RNA-based drug designing, Protein-based drug designing, Pathway based drug designing. Computer Aided Drug Designing (CADD) - Sequence and structural analysis, Active sites, molecular interaction, Docking studies, Molecular dynamic simulation and Monte-Carlo simulation techniques. Electrostatic complementarity - Master equation approach, Poisson-Boltzmann calculation, Correlation of electrostatic potential, Regression analysis of free energy; Drug administration and drug effectiveness - Diffusion and drug dispersion, diffusion in biological systems, drug permeation through biological barriers, drug transport by fluid motion, pharmacokinetics of drug distribution, ADMETox. Drug delivery systems - Drug modification, controlled drug delivery systems, computational drug delivery, FEM based modeling of drug delivery. Case studies - Drug designing, controlled delivery of systematic therapy.

**TEXTBOOKS / REFERENCES:**


1. Saltzman W.M, *Drug Delivery-Engineering Principles for Drug Therapy*, Oxford University Press, 2001.
2. Vinter J G and Gardner M, *Molecular Modeling and Drug Design*, CRC Press, 2001.
3. Smith D A, Van de Waterbeemd H and Walker D K, *Pharmacokinetics and Metabolism in Drug Design*, Wiley-VCH, 2001.


**Outcomes:**

- Knowledge of the fundamentals of drug design and simulation
- Knowledge of different methods of drug study and characterisation

**16BM754 ADVANCED SIGNAL PROCESSING 3-0-0-3**

**Objectives:**

- To learn advanced transform techniques like wavelets and DCT
- To learn statistical parametric and non-parametric modeling of biosignals and power spectrum estimation techniques
- To learn various feature extraction techniques for evaluating the biosignals
- To learn classification techniques for applying in certain diagnosis

Multi-resolution Signal and Noise analysis: Signal analysis, DCT, STFT, WT; Spectral Estimation: parametric and non-parametric methods; Signal Modelling: auto-regressive, moving-average, auto-regressive and moving-average, linear predictive modeling and application to the biosignals; Linear and Nonlinear Filtering: mean-average filter, median filter, derivative filter,

FIR and IIR filters (low-pass, high-pass, and band-pass, and notch), Weiner filter, LMS and Kalman filtering algorithms, SVD filtering and homomorphic signal processing; Bio-signal Processing: Independent and Principal Component Analyses (ICA and PCA) and use in bio-signal separation; introduction to detection, estimation, and classification problems, Feature Extraction: temporal and spectral features, DCT features, STFT features, wavelet features, higher order statistics (HOS), and information-theoretic features; Event Detection and Classification: classifiers (Euclidean and Mahalonobis distances, Linear discriminants, SVM, NN, GMM, KLD). Computer aided diagnostic system: ECG beat recognition, heart sound and murmurs classification, Brain disorders, EMG signal filtering, and HRV analysis; Biosignal Compression: lossless, DCT and DWT.

**TEXTBOOKS / REFERENCES:**

1. Oppenheim A V, Schafer R W and Buck J R, *Discrete-Time Signal Processing*, Third Edition, Prentice Hall, 2009.
2. Rangayyan R M, *Biomedical Signal Analysis - A Case-Study Approach*, Second Edition, Wiley -IEEE Press, 2015.
3. Kay S M, *Fundamentals of Statistical Signal Processing; Practical Algorithm Development*, Vol . III, Prentice Hall, 2013.
4. Begg R, Palaniswami M and Lai D T H, *Computational Intelligence in Biomedical Engineering*, CRC Press, 2007.

**Outcomes:**

The student will be able to

- Apply digital filtering and classical spectral analysis to evaluate the biosignals
- Apply modern spectral analysis, wavelet and time-frequency analysis on various biosignals
- To apply appropriate feature extraction techniques for evaluating the signals
- Apply a range of classification techniques

**16BM755 TISSUE ENGINEERING 3-0-0-3**

**Objectives**

- To understand cellular organisation and Morphogenesis
- To understand scaffolding materials and processing technologies
- To understand various tissue engineering models

Definitions; Goals of tissue engineering; Biology for tissue engineering: Cellular organization, Organization of cells into higher-ordered structures, Cell-ECM interactions, Matrix molecules and ligands, Signaling for tissue engineering, Morphogenesis, Cell differentiation. Control of tissue development: Mechanochemical switching between growth and differentiation, regulation and growth factors. Biomaterials in tissue engineering: Cell interaction with polymers, matrix effects, scaffolding materials, scaffold processing technologies – salt leaching, polymer phase separation, solid freeform fabrication, gas foaming, electrospinning, self assembly, ceramic scaffold processing; Material modification and properties. Models for tissue engineering (selected case studies will be covered): Issues in kinetics, transport and mechanics; Molecular interactions with cells, molecular and cell transport through tissues, cell and tissue mechanics - Tissue engineering applications (selected case studies will be covered): Cardiovascular systems, tendons and ligaments, bones, cornea, periodontia, craniofacial structures, red-blood cell substitutes, nerve regeneration, insulin replacement, fetal tissue engineering, renal replacement, stem cells in tissue engineering.

**TEXTBOOKS / REFERENCES:**

1. Lanza R P, Langer R and Vacanti J (Eds.), *Principles of Tissue Engineering*, Fourth Edition, Academic Press, 2014.
2. Ma P X and Elisseeff J (Eds.), *Scaffolding in Tissue Engineering*, CRC Press, 2006.

**Outcomes:**

- Knowledge of cellular organisation, morphogenesis and cell differentiation
- Knowledge of scaffolding materials and processing
- Knowledge of tissue engineering models

**16BM756 BIOFLUID MECHANICS 3-0-0-3**

**Objectives:**

- To learn the basics of fluid flow – properties and effect of temperature and pressure
- To learn about various kinds of fluid flow
- Knowledge of fluid transport in biological systems
- To learn about transport of gases and nutrients

Introductory Fluid mechanics – Types of fluids, fluid properties, Effect of temperature and pressure on fluid properties, Conservation relations and boundary conditions, Fluid statics, modes of fluid transportation, laminar and turbulent flows, Application of momentum balances - Flow between fixed and moving parallel plates, flow through cylindrical pipe, flow through annulus, flow between rotating cylinders, Internal vs. External flows, boundary layer formation and boundary layer theory, flow around a fixed cylinder and sphere, flow around a slowly rotating sphere, Friction loss in flow through pipes, Transport through porous media. Introduction to Biological systems – Constituents and properties of blood, Cell Structure, Relative importance of convection and diffusion, Transport within the cell, Transport across cell membrane, Transcellular transport, Physiological transport systems – cardio vascular systems, Respiratory system, Gastrointestinal tract, Liver Kidneys, Integrated organ function. Fluid flow in veins, arteries and tissues – Oscillating flow in circular tubes, Entrance effects in circular tubes, flow in rigid and flexible tubes, flow in a collapsing pipe subjected external force and pressure correlations, Flow in branching arteries, Flow in sudden contraction enlargements as applied to cardiovascular systems, and Flow through pipe varying in diameter, Arterial fluid dynamics and hemodynamics – Heart valve hemodynamics, Fluid dynamics of Reconstructive surgery for congenital heart diseases, Heart pumping capacities for all the above studies. Heat and Mass Transport in Biological Systems – Transport of gases and vital nutrients in between blood and tissues, Oxygen-Hemoglobin equilibrium, Oxygen delivery to tissues, Drug transport in solid tumors.

**TEXTBOOKS / REFERENCES:**

1. Kleinstreuer C, *Biofluid Dynamics: Principles and Selected Applications*, CRC/Taylor and Francis, 2006.
2. Truskey G A, Yuan F and Katz D F, *Transport Phenomena in Biological Systems*, Second Edition, Pearson/Prentice Hall, 2009.
3. Cooney D O, *Biomedical Engineering Principles: An Introduction to Fluid, Heat and Mass Transport Processes*, M. Dekker, 1976.
4. Sharma K L, *Transport Phenomena in Biomedical Engineering: Artificial Organ Design and Development and Tissue Engineering*, McGraw-Hill, 2010.

**Outcomes:**

- Knowledge of the basics of fluid flow
- Understanding of the different forms of fluid transport in biological systems

**16BM757 BIOMEDICAL NANOTECHNOLOGY 3-0-0-3**

**Objectives**:

- To understand the characteristics of nanoparticles, nanotubes, quantum dots and nanoprobes
- To understand the use of nanoparticles as biosensors

Nanotechnology in Biology and Medicine – Self-assembled Organic nanotubes - Self assembled Gold Nano particles with organic linkers - Nano wires for biomolecular sensing – Nucleoprotein-based membrane systems - Quantum dots - Nanopore methods for DNA detection and sequencing - nanoimaging - Three-Dimensional Aberration-Corrected Scanning Transmission Electron Microscopy for Biology - Development and Modeling of a Novel Self-Assembly Process for Polymer and Polymeric Composite Nanoparticles - Optical Nanobiosensors and Nanoprobes. Biomolecule Sensing Using Surface Plasmon Resonance - Enzyme Quantum Dots as Tracers for DNA Electrochemical Sensing Systems - Nanobiosensors: Carbon Nanotubes in Bioelectrochemistry - Nanoparticles in Medical Diagnostics and Therapeutics - Microtubule-Dependent Motility during Intracellular Trafficking of Vector Genome to the Nucleus: Sub-cellular Mimicry in Virology and Nanoengineering - Gene Detection and Multispectral Imaging Using SERS. Nanoprobes and Nanostructures - Integrated Cantilever-Based Biosensors for the Detection of Chemical and Biological Entities

**TEXTBOOKS / REFERENCES:**


1. Malsch N H, *Biomedical Nanotechnology*, Taylor and Francis, 2005.
2. Lockwood D J, *Introduction to Nanoscale Science and Technology*, Kluwer Academic Publishers, 2004.
3. Vo-Dinh T, *Nanotechnology in Biology and Medicine – Methods, Devices and Applications*, CRC Press, 2003.
4. Mozafari R M, *Nanomaterials and Nanosystems for Biomedical Applications*, Springer, 2007.
5. Ratner M and Ratner D, *Nanotechnology – A Gentle Introduction to the Next Big Idea*, Prentice Hall, 2002.


**Outcomes:**

- Knowledge of the use of nanostructures for biomedical applications

**16BM758 METHODS FOR MEDICAL DIAGNOSTICS 3-0-0-3**

**Objectives:**

- To understand the relevance of clinical tests in proper diagnosis
- To understand the use of some common haemotological and biochemical tests

Introduction to Diagnostics – History, Mechanisms of disease, Blood Composition, Blood Collection procedures, Blood Cell Development, White blood cells, Red blood cells, hemoglobin / hematocrit, platelets, Other hematology tests, Coagulation, Urinalysis - kidney function, chemical tests, occult blood, Blood Chemistry – Overview, glucose, metabolic tests, hormones, enzymes, tests for cardiac muscle injury, lipids, Genetic testing, Forensics, Cytology / Histology / Pathology, Arterial Blood Gases / electrolytes, Endoscopic studies, Medical Imaging - Radiography, CT Scan, MRI, Sonography, Special Organ Study – Heart, Brain, Lungs, Nuclear medicine.

**TEXTBOOKS / REFERENCES:**


1. Fischbach F and Dunning M B, *A Manual of Laboratory and Diagnostic Tests*, Ninth Edition, Wolters Kluwer Health: Lippincott Williams *and* Wilkins, 2014.
2. Pagana K and Pagana T J, *Mosby's Diagnostic and Laboratory Test Reference*, Eleventh Edition, Elsevier Mosby, 2013.
3. Wilson D, *McGraw-Hill's Manual of Laboratory and Diagnostic Tests*, McGraw-Hill, Medical Pub. Division, 2008.
4. Chernecky C C and Berger B J, *Laboratory Tests and Diagnostic Procedures*, Sixth Edition, Saunders, 2013.
5. Dirckx J, *Laboratory Tests and Diagnostic Procedures in Medicine*, Health Professions Institute, 2004.

**Outcomes:**

- Ability to recognize the range of certain haemotological and biochemical parameters
- Understanding of the importance of clinical and diagnostic tests

**16BM759 LASER INSTRUMENTATION FOR BIOMEDICAL APPLICATIONS 3-0-0-3**

**Objectives:**

- To understand laser-tissue interaction
- To understand the operation of laser equipment and their application

Basic optical theory - nature of electromagnetic radiation, interaction of radiation with matter, reflection, refraction, polarization, Laser fundamentals, laser beam characteristics, Q-switching, mode locking, continuous wave, beam quality (laser cavity modes), types of lasers, energy and power; Laser interaction - Absorption, reflection, refraction and polarization, optical properties of materials, tissues – laser interaction with tissues - pathology of laser reaction in tissues - thermal effects - non thermal reactions of laser radiation; Laser instrumentation - Doppler flowmetry - Laser flow cytometry - single cell separation - micro irradiation, Laser fluorescent micro irradiation - Laser eye instrumentation; Laser tissue transillumination & diaphanography - Speckle interferometry, reflectance in tumour diagnostics, holography - Application Safety with biomedical Lasers.

**TEXTBOOKS / REFERENCES:**

1. Niemz M H, *Laser-Tissue Interactions: Fundamentals and Applications*, Second Edition, Springer, 2014.
2. Tuchin V V, *Tissue Optics: Light Scattering Methods and Instruments for Medical Diagnosis*, Third Edition, SPIE Publications, 2015.
3. Goldman L, *The Biomedical Laser Technology and Clinical Applications*, Springer-Verlag, 1981.
4. Wolbarsht M L, *Laser Applications in Medicine and Biology*, Springer, 1991.

**Outcomes:**

- Understanding of the interaction between lasers and tissue
- Knowledge of the operation of some laser-based biomedical equipment

**16BM760 BIOSTATISTICS 3-0-0-3**

**Objectives:**

- Recognise different kinds of data in public health and clinical studies
- Interpret differences in data distributions
- Understanding of standard methods of data collection, manipulation and analysis
- Understanding of the basic principles and uses of linear regression models

Probability in the Health Sciences – Measurement and Measurement Sciences, Sampling and Statistical Inference, Frequency Distribution, Measures of Central Tendency and Dispersion; Bayes' Theorem and Screening Tests; Probability Distributions – Poisson, Binomial and Normal; Observational Data – Description and Analysis, Random Sampling; Population parameters and sample statistics; Measures of dispersion; Comparison with hypothetical value; two or more paired or unpaired groups, Measures of association, prediction of values; Estimation and Testing of Hypotheses, Regression and Correlation; Analysis of Variance

**TEXTBOOKS / REFERENCES:**

1. Daniel W W, *Biostatistics : Basic Concepts and Methodology for the Health Sciences*, Ninth Edition, Wiley India Pvt. Ltd, New Delhi, 2010.
2. Glantz S A, *Primer of Biostatistics*, Seventh Edition, McGraw-Hill Medical Pub., New York, 2011.

**Outcomes:**

- Ability to organize, summarise and display quantitative data
- Ability to carry out and interpret different tests of statistical significance

**16BM761 VIRTUAL INSTRUMENTATION FOR MEDICAL SYSTEMS 3-0-0-3**

**Objectives**:

- To learn the fundamentals of Virtual Instrumentation
- To learn to acquire, analyse and present biomedical data using LabVIEW

Concepts of Virtual instrumentation systems; Data Acquisition and Analysis using LabVIEW; Design and implementation of virtual instrumentation systems for ECG, Pulse Oximetry and EEG signal acquisition and analysis.

**TEXTBOOKS / REFERENCES:**

1. Gupta S and John J, *Virtual Instrumentation Using LabVIEW*, Second Edition, Tata McGraw-Hill, 2010.
2. Bishop R, *LabVIEW 2009: Student Edition*, Prentice Hall, 2010.
3. Olansen J B and Rosow E, *Virtual Bio-Instrumentation: Biomedical, Clinical and Healthcare Applications in LabVIEW*, Prentice Hall, 2002.
4. Relevant Data Sheets and User Manuals

**Outcomes:**

- Ability to acquire, analyse and present data using LabVIEW
- Development of simple biomedical data acquisition systems, using LabVIEW

**16BM762 SPECIAL TOPICS IN BIOMEDICAL IMAGE PROCESSING 3-0-0-3**

**(Pre-requisite: 16BM622 BIOMEDICAL IMAGE PROCESSING)**

**Objectives:**

- To introduce image restoration and advanced image segmentation techniques
- To understand in detail, the features useful for representing and describing regions of interest in biomedical images
- To learn image processing applications, including reconstruction and registration that deal with multiple images

Image Restoration - Spatial filtering, Frequency domain filtering, Inverse filtering, Wiener filtering, Constrained least squares filtering, Geometric mean filter, Wavelet filtering, Applications: Restoration of Nuclear Medicine and SPECT images; Image Segmentation - Morphological watersheds, Markov random fields, Gaussian mixture models, Active contours, Applications: Detection of breast boundary in mammograms, Detection of masses in breast ultrasound images; Image Representation and Description - Shape and Texture features, oriented patterns, Applications: Analysis of breast masses, Analysis of ligament healing; Image Reconstruction from Projections - The Fourier slice theorem, Back projection, Algebraic reconstruction techniques, Application: Analysis of tumors in Neuroblastoma; Image Registration - Linear transformation, Non-linear transformation, Non-rigid transformation, Feature-based and voxel-based registration, Application: Analysis of bilateral asymmetry in mammograms.

**TEXTBOOKS / REFERENCES:**

1. Gonzalez R C and Woods R E, *Digital Image Processing*, Third Edition, Prentice Hall, 2007.
2. Milan Sonka, Vaclav Hlavac and Roger Boyle, *Image Processing, Analysis and Machine Vision*, Third Edition, Cengage Learning, 2007.
3. A. Ardheshir Goshtasby, *2-D and 3-D Image Registration for Medical, Remote Sensing, and Industrial Applications*, John Wiley and Sons, 2005.

4. Rangayyan R M, *Biomedical Image Analysis*, Fifth Edition, CRC Press, 2005.

**Outcomes:**

- Students will be able to restore biomedical images from their noisy versions
- Students will be able to apply advanced segmentation techniques to accurately segment regions of interest in biomedical images
- Students will be able to identify and extract appropriate features to represent different kinds of biomedical conditions
- Students will be able to reconstruct 3D images from 2D slices
- Students will be able to register intra-modality/inter-modality images for advanced processing

**16BM763 MAMMOGRAM IMAGE ANALYSIS 3-0-0-3**
**(Pre-requisite: 16BM622 BIOMEDICAL IMAGE PROCESSING)**

**Objectives:**

- To introduce the various indications of breast cancer on mammography
- To introduce the standards for breast cancer representation and diagnosis
- To understand the advantages of computer aided diagnosis (CAD)
- To learn various image processing algorithms that can be applied for mammogram analysis

X-ray imaging - Breast cancer and mammography - Indicators of breast cancer: Masses, Microcalcifications, Architectural distortion, Bilateral asymmetry - Breast Imaging-Reporting and Data System (BIRADS) standardization - Computer aided diagnosis (CAD) of breast cancer - Pre-processing in mammograms - Detection of suspicious regions - Shape and texture analysis of masses and microcalcifications - Analysis of oriented patterns for characterization of bilateral asymmetry and architectural distortion - Image registration for bilateral analysis - Information fusion in mammograms - Pattern classification and diagnostic decision - Measures of diagnostic accuracy - Content-based retrieval and analysis in mammograms.

**TEXTBOOKS / REFERENCES:**

1. Tinku Acharya and Ajoy K Ray, *Image Processing- Principles and Applications*, Wiley, 2005.
2. Gonzalez R C and Woods R E, *Digital Image Processing*, Third Edition, Prentice Hall, 2007.
3. Rangayyan R M, *Biomedical Image Analysis*, Fifth Edition, CRC Press, 2005.
4. Robin N. Strickland (Eds.), *Image-Processing Techniques for Tumor Detection*, CRC Press, 2002.
5. F. Diekmann (Eds.), *Digital Mammography*, U. Bick, Springer, 2010.

**Outcomes:**

- Students will be able to apply appropriate algorithms for processing mammograms
- Students will be able to build CAD systems for breast cancer detection and diagnosis
- Students will be able to propose new techniques for automated breast cancer diagnosis, aiming better performance

**16BM764 MEDICAL IMAGING TECHNIQUES 3-0-0-3**

**Objectives:**

- To lay the engineering foundations for the understanding of planar X-ray, X-ray CT, planar scintigraphy, SPECT and PET, ultrasound imaging and MRI
- To introduce in detail the physics, instrumentation, image characteristics, clinical applications and recent developments of each medical imaging modalities
- To provide the basic understanding of patient safety and quality in medical imaging

Introduction to medical imaging signals and systems; General image characteristics; Planar X-ray, X-ray Computed tomography (CT), Nuclear medicine (Planar Scintigraphy, PET and SPECT), Ultrasound imaging, Magnetic resonance imaging (MRI): basic physical principles, image formation, instrumentation, data acquisition strategies, image characteristics like SNR, spatial resolution and CNR, clinical applications, recent developments of each modality.

**TEXTBOOKS / REFERENCES:**

1. Andrew G. Webb, *Introduction to Biomedical Imaging*, Wiley-IEEE Press, 2002.
2. Nadine Barrie Smith and Andrew Webb, *Introduction to Medical Imaging: Physics, Engineering and Clinical Applications*, Cambridge University Press, 2010.
3. Jerrold T. Bushberg, J. Anthony Seibert, Edwin M. Leidholdt Jr. and John M. Boone, *The Essential Physics of Medical Imaging*, Third Edition, Lippincott Williams and Wilkins, 2011.
4. Paul Suetens, *Fundamentals of Medical Imaging*, Second Edition, Cambridge University Press, 2009.
5. Jerry L. Prince, Jonathan Links, *Medical Imaging Signals and Systems*, Second Edition, Pearson, 2014.

**Outcomes:**

- Students will be able to recognise the need for different imaging modalities and understand the terminology of biomedical imaging
- Students will be able to understand the basic physics and engineering of each modality
- Students will be able to know the clinical application of each modality and possibly suggest the most suitable modality for a given clinical case
- Students will be able to know the recent developments taking place in each medical imaging modality

**16BM765 SPECIAL TOPICS IN BIOMEDICAL INSTRUMENTATION 3-0-0-3**
**(Pre-requisite: 16BM611 BIOMEDICAL INSTRUMENTATION)**

**Objectives:**

- To understand the challenges in biomedical signal measurement
- To understand various protection mechanisms and other signal conditioning circuits in biomedical devices / systems

Biomedical Transducers – Signals and Noise in Measurement, Measurement System Characteristics, Accuracy, Error and Calibration, Measurement of Pressure, Flow, Motion, Force and Temperature; Grounding; Protection Circuits; Isolation; Active Filters – Low-pass, High-pass, Band-pass and Notch; Analog to Digital Converters – Dual Slope, Σ-Δ.

**TEXTBOOKS / REFERENCES:**

1. Northrop R B, *Analysis and Application of Analog Electronic Circuits to Biomedical Instrumentation*, Second Edition, Boca Raton, CRC Press, 2012.
2. Togawa T, *Biomedical Transducers and Instruments*, Second Edition, Boca Raton, CRC Press, 2011.
3. Webster J G, *Medical Instrumentation - Application and Design*, Third Edition, Wiley, New York, 2009.
4. Pallas-Areny R and Webster J G, *Sensors and Signal Conditioning*, Vol. 1, Second Edition, John Wiley and Sons Inc., New York, 2001.
5. Selected Papers from IEEE Transactions

**Outcomes:**

- Knowledge of various sensors used for measuring different physiological parameters
- Ability to design various protection and signal conditioning circuits for biomedical devices

**16BM766 BIOMEMS 3-0-0-3**

**Objectives:**

- Understanding of fluid low at micro level
- Understanding of MEMS design, fabrication processes and packaging
- Exposure to the use of MEMS for biomedical and chemical sensing

Introduction to BioMEMS and Microsystems technology: Biochips / biosensors and introduction to device fabrication, Introduction to Cell biology; DNA & Protein chemistry, Microfluidics; Biochip Sensors & detection methods; Potential of Micro-fluidics and introductory continuum mechanics at small scales, Microarrays and Lab-on-chip devices, Introduction to MEMS Design; Micro-fluidics: Continuum mechanics at small scales: Basics of micro-fluidics; Gas Flows; Liquid flows; Boundary conditions; low Reynold's number flows; Entrance effects, surface tension; Electro-kinetic techniques like electrophoresis; Electro-osmosis and dielectrophoresis; Micro-fluidics for internal flow control (micropumps and micro-valves, devicebuilding and characterization); Micromixer design and characterization, Micro-fluidics for life sciences and chemistry; Microsystems-fabrication processes: Review of basic fabrication processes for silicon: Introduction to microelectronic fabrication; Optical lithography; Photo-resists; Non optical lithography techniques; LIGA processes. Design Considerations: Vacuum science and plasmas; Etching techniques; Physical vapor deposition (evaporation and sputtering); Chemical vapor deposition; Review of basic fabrication processes for polymers : Polymer materials for micro-systems; Polymeric micromachining technology like soft lithography; Bulk and surface micromachining; Replication technologies - Laser machining, Micro-stereo lithography, Micro-molding; Assembly and packaging of micro-systems; Biocompatibility of materials and processes. Overview of Lab-on-chip technology / biomedical and chemical sensors, specific cases: Integrated gene analysis systems; Petri dish on a chip technology (Integrated trapping, culture, growth, lysis and analysis of pathogenic bacteria); Single cell and single molecule analysis using lab-on-chip techniques. Pharmaceutical analysis using lab-on-chip technology. Biomedical and chemical sensors: Electrochemical. Optical (labeled and unlabeled). Piezoelectric sensors.

**TEXTBOOKS / REFERENCES:**

1. Madou M J, *Fundamentals of Microfabrication*, Second Edition, CRC Press - Taylor and Francis Group, Florida, 2002.
2. Wang W, Soper S A (Ed.), *BioMEMS Technologies and Applications*, CRC Press - Taylor and Francis Group, Florida, 2006.
3. Bashir R, Werely S T and Ferrari M, *Biomolecular Sensing, Processing and Analysis*, Springer Science and Business Media LLC, New York, 2006.
4. Nguyen N T and Werely S T, *Fundamentals and Applications of Microfluidics*, Artech House Inc., Massachusetts, 2006.
5. Alberts B, Johnson A, Lewis J, Raff M, Roberts K, Walter P and Sand G, *Molecular Biology of the Cell*, Taylor and Francis Group, Florida, 2002.

**Outcomes:**

- Knowledge of MEMS design requirements and fabrication processes
- Knowledge of the use of MEMS for biomedical and biochemical sensing

**16BM767 MICROWAVE BIOMEDICAL TECHNOLOGY 3-0-0-3**

**Objectives:**

- Understanding of the basics of microwave radiation and propagation
- Understanding the electrical properties of biological tissues
- Understanding the effect of microwave radiation on tissues

Introduction to electromagnetic spectrum – applications of electromagnetic frequency bands – concept of low, high and radio frequency – microwave band and characteristics – Microwave propagation – conductors, insulators and dielectrics – conductivity, permittivity and permeability

of tissues - propagation mechanism – transmission line principles. Electrical properties of biological materials – penetration of waves in to biological tissues – microwave heating – Diagnostic Techniques employing electromagnetic waves - EMI/EMC Principles for Biomedical Equipment design - EM Absorbers - Exposure guides and standards

**TEXTBOOKS/REFERENCES:**

1. Vorst A V, Rosen A and Kotsuka Y, *RF / Microwave Interaction with Biological Tissues*, Hoboken, NJ: John Wiley and Sons, 2006.
2. Kraus J D and Fleisch D A, *Electromagnetics with Applications*, Fifth Edition, McGraw-Hill India, 2010.
3. Paul C R, *Introduction to Electromagnetic Compatibility*, Second Edition, Wiley India Private Limited, November 2010.

**Outcomes:**

- Understand the Concept of Field – Medium parameters
- Understand Plane Wave model and Wave – Medium Interaction
- Construct Wave propagation Model for a biological tissues
- Ability to analyze wave-tissue interaction and interpret its relevance

**16BM768 SPECIAL TOPICS IN BIOMEDICAL ENGINEERING 3-0-0-3**

**Objective:**

- To motivate and encourage the students to take part in Design / Paper / Poster Contests of International standing, of relevance to Biomedical Engineering

The student may be allowed to credit a First / Second Place / Best Paper Award at programme approved, National / International Contests / Conferences / Journals in the area of Biomedical Engineering, in lieu of Elective III offered in the third semester. The student will have to seek the prior approval of the Programme Coordinator / Department Chair, in writing, before submitting the idea / proposal for the contest. The Award will have to be announced in time for the deadline of the registration of courses, for the third semester.

**Outcome:**

- Motivate and encourage out-of-the-box thinking
- Exposure to the state-of-the-art in the field

**16BM77X [----------] 3-0-0-3**

**Objective:**

- To encourage the use of online courses
- To make use of the vast resources of the Internet, to learn at a different pace

The student may be allowed to credit any course - relevant to Biomedical Engineering - leading to a Certificate offered by agencies like NPTEL / GIAN or equivalent, in lieu of Elective III offered in the third semester. The student will have to seek the prior approval of the Programme Coordinator / Department Chair, in writing, before registering for such online courses. The request for such registration shall include the curriculum / syllabus of the course, the lecture plan and examination schedule, where applicable and shall be submitted for approval to the Programme Coordinator, at least a month before the deadline for the registration of courses, for the third semester. The third semester Gradesheet of such a student, shall indicate the name of the course as mentioned in the Certificate, with the course code 16BM77X, where 'X' will indicate the serial order of such courses as they are registered.

**Outcomes:**

- Exposure to specialized subjects and topics beyond the expertise of the University
- Value addition to the students

**16BM691 INTERNSHIP 0-0-0-2**

The student shall, at the end of the second semester, in consultation with the Faculty Advisor / Co-ordinator, undertake an internship for a minimum duration of five consecutive weeks, in a reputed hospital, company or laboratory involved with biomedical instrumentation or biotechnology. This is intended to orient the student for a suitable specialization as well as his/her choice of electives and project in the remaining two semesters. At the end of the internship, the student will be evaluated on the basis of a written report, submitted in the specified format as well as a Viva-Voce examination to be conducted by a panel, consisting of a minimum of two faculty members. The evaluation will be reflected in the credits / grade sheet of the third semester.

**16BM662 OPEN / LIVE-IN LABS 0-0-0-1**

The Open Lab / Live-in Labs aims at helping the student to design, develop and realize new experiments relevant to the Biomedical Engineering program. It seeks to provide students an exposure to seek / observe real world biomedical problems through Live-in Labs and to develop appropriate technical solutions. It will enable the students to conceptualise, design and develop prototype systems for medical applications. A review team will conduct a one-time evaluation of the authenticity of the project / Lab experiment options/ utilization of existing lab tools / manual preparation / demonstration of hardware/software.

**16BM797 PROTOTYPING OF BIOMEDICAL SUB-SYSTEMS 0-0-0-3**

During the third semester, the student shall expand on the ideas and concepts of instrumentation, learnt in the first two semesters, to design, analyse, simulate and prototype a system to be used for biomedical applications. The project will be evaluated periodically throughout the semester.

**16BM798 / 799 DISSERTATION 0-0-0-22**

In Phase 1 of the Dissertation, the student will, with the help of a senior faculty member, identify a particular problem of interest in biomedical engineering and over the period of the third semester, study the state-of-the-art in the area of interest and develop a new technique / algorithm / circuit / device to obtain demonstrably better results than those presently available. This phase of the Dissertation will be evaluated on the basis of periodic reviews conducted throughout the semester and a Viva Voce examination to be conducted in December, which shall be attended by the Program Co-ordinator and at least one other faculty member. Phase 1 of the dissertation will be for 8 credits.

During the second phase of the Dissertation, the student shall continue with the work initiated in Phase 1, in order to achieve the stated objectives of the project. At the end of this phase, the student shall submit a dissertation in the prescribed format, detailing the work done, the results obtained and the inferences thereof, along with an appropriate bibliography. The project will be evaluated on the basis of periodic reviews conducted throughout the semester and a final examination at the end of the fourth semester, which shall be attended by at least one eminent academician / researcher / technologist in the areas of biomedical instrumentation / engineering, from outside the University. Phase 2 of the Dissertation will be worth 14 credits.