BIOMEDICAL ENGINEERING

M. Tech. BIOMEDICAL ENGINEERING

Program Structure (Applicable to 2023 admission onwards)

YEAR	FIRST SEMESTER						SECOND SEMESTER					
	SUB CODE	SUBJECT NAME	L	T	P	C	SUB CODE	SUBJECT NAME	L	T	P	C
I	MAT ****	BIOSTATISTICS AND LINEAR ALGEBRA	4	0	0	4	BME ****	BASIC CLINICAL SCIENCES	4	0	0	4
	BME ****	ADVANCED BIOMEDICAL INSTRUMENTATION	4	0	0	4	BME ****	MEDICAL IMAGE PROCESSING	4	0	0	4
	BME ****	APPLIED BIOMEDICAL SIGNAL PROCESSING	4	0	0	4	BME ****	ELECTIVE I	4	0	0	4
	BME ****	BIOMATERIALS AND BIOMECHANICS	4	0	0	4	BME ****	ELECTIVE II	4	0	0	4
	BME ****	HUMAN ANATOMY AND PHYSIOLOGY	4	0	0	4	BME ****	ELECTIVE III	4	0	0	4
	HUM ****	RESEARCH METHODOLOGY AND TECHNICAL COMMUNICATION*	1	0	3	-	*** ****	OPEN ELECTIVE	3	0	0	3
	BME ****	BIOMEDICAL INSTRUMENTATION LAB	0	0	3	1	HUM ****	RESEARCH METHODOLOGY AND TECHNICAL COMMUNICATION*	1	0	3	2
	BME ****	BIOMEDICAL SIGNAL PROCESSING LAB	0	0	3	1	BME ****	MEDICAL IMAGE PROCESSING LAB	0	0	3	1
	BME ****	BIOMATERIALS AND BIOMECHANICS LAB	0	0	3	1	BME ****	BIOMEDICAL RESEARCH LAB	0	0	3	1
	Total					**23**						**27**
	THIRD AND FOURTH SEMESTER											
II	BME 6098	PROJECT WORK							**0**	**0**	**0**	**25**

*TAUGHT IN BOTH SEMESTERS AND EVALUATED AND CREDITED IN THE SECOND SEMESTER

**LAB COURSES 2 & 3 AND 4&5 MAY BE COMBINED INTO ONE BY EITHER ALLOTTING 6 Hrs/WEEK OR 3 Hrs/WEEK WITH A PROVISION FOR MINI PROJECT/ASSIGMENTS

PROGRAM ELECTIVES		OPEN ELECTIVES	
COURSE CODE	COURSE TITLE	COURSE CODE	COURSE TITLE
BME ****	NANOMATERIALS AND CHARACTERIZATION TECHNIQUES	BME ****	PHYSIOLOGICAL CONTROL SYSTEMS
BME ****	BIOMETRICS FOR HEALTHCARE SYSTEM	BME ****	MEDICAL INFORMATICS
BME ****	INTERNET OF MEDICAL THINGS		
BME ****	CELL CULTURE TECHNIQUES AND STEM CELL BIOLOGY		
BME ****	EMBEDDED SYSTEMS		
BME ****	EXPERIMENTAL TECHNIQUES IN BIOMEDICAL RESEARCH		
BME ****	MACHINE LEARNING		
BME ****	PATTERN RECOGNITION		
BME ****	TISSUE ENGINEERING		
BME ****	AUGMENTED REALITY AND VIRTUAL REALITY		
BME ****	HEALTH INFORMATION SYSTEMS		
BME ****	DIGITAL PATHOLOGY AND DIGITAL IMAGING		
BME ****	INNOVATION AND ENTREPRENERSHIP		

Course Content

SEMESTER 1

BME ****BIOSTATISTICS AND LINEAR ALGEBRA [4 0 0 4]

Vector Spaces, subspaces and linear transformations, matrices-basic operations, determinants, eigen values, eigen vectors, solution of a system of linear equations using matrices. Introduction to statistics and study design: Introduction, Types of variables- logarithmic transformations, graphical representation of data. Measures of central tendency, dispersion. Significance of statistics to biological problems, experimental studies; randomized controlled studies, historically controlled studies. Multivariate data- Correlation and simple linear regression: Karl Pearson correlation coefficient, Spearman Rank correlation coefficient, simple linear regression, regression model fit, Multiple linear regression models, random effects models Principles of statistical inference: Parameter estimation, hypothesis testing. Test statistics- t-test, F distribution, independent and dependent sample comparison, non-parametric tests-Wilcoxon Signed Rank Test, Wilcoxon Mann-Whitney Test. Basics of study design-cohort studies, case control studies, outcomes, odd ratio, and relative risks. Biological study designs- Concept of ANOVA using Completely randomized design, Random block design, stratified design factorial design, cluster design. Optimization strategies with case studies. SAS data set operations: Read raw data; write, merging, sub setting, sort, format data sets, output delivery system. SAS representations. SAS basic statistical procedure.

References

1. Biostatistics Alvin E. Lewis McGraw-Hill Professional Publishing 2013
2. Statistics and Numerical Methods in BASIC for Biologists J.D. Lee and T.D. Lee Van Nostr and Reinhold Company 1982
3. Statistical Analysis of Gene Expression Microarray Data T.P. Chapman CRC 2003
4. Matrix Algebra useful for Statistics, Second Edition, by Searle, S. R & Khuri A, I. (2017). John Wiley & Sons, New Jersey.

BME **** ADVANCED BIOMEDICAL INSTRUMENTATION [4 0 0 4]

Principles of basic sensors, bio-potentials & electrodes, transducers, chemical biosensors, Blood pressure & Blood flow measurements, respiratory plethysmography. Therapeutic and prosthetic devices: Heart lung machine, pacemaker & Defibrillator, Ventilators, Lithotripsy. Medical Imaging systems: Radiography, Computed tomography, MRI, Nuclear medicine, and Ultrasonography.

SDL: MEMS for Biomedical Applications, Source: NPTEL, Course Name: Lecture – 32 - MEMS for Biomedical Applications (Bio-MEMS) Instructor: Prof. Santiram Kal, IIT Kharagpur; Duration: 1.45Hr

References:

1. John G. Webster, Amit J. Nimunkar," Medical Instrumentation, Application and Design Edition 5" John Wiley & Sons,
2. R.S. Khandpur, "Handbook of Biomedical Instrumentation", McGraw-Hill Education, 2014.
2. Leslie Cromwell et.al., "Bio Medical Instrumentation", PHI, 1990.
3. Geddes and Baker, "Principles of Applied Bio-Medical Instrumentation", John Wiley, 2008.
4.R. Aston," Principles of Biomedical Instrumentation and Measurement" Merril Purl Co., 1991.

BME **** APPLIED BIOMEDICAL SIGNAL PROCESSING [4 0 0 4]

Basics of Discrete-Time Signal, Biomedical signal origin & dynamics, Frequency-domain Analysis for Spectral Estimation, Filtering techniques for Removal of artifacts, Event Detection in Biomedical signals, Biomedical Signal Waveform analysis, Modeling of Biomedical systems, Time-Frequency analysis.

SDL: Analysis of nonstationary and multicomponent signals*

References:

1.Proakis J G and Manolakis D G, Digital Signal Processing: Principles, Algorithms, and Applications, 3rd edition, Prentice Hall, 2002.
2.*Rangaraj M Rangayyan, "Biomedical Signal Analysis - A case study", John Wiley and Sons, Singapore, 2002.
3.Monson H. Hayes, "Statistical Digital Signal Processing and Modeling", Wiley student edition, 2009.
4.Cohen, L. Time-Frequency Analysis: Theory and Applications. 1st edition, Prentice Hall, 1994.
5.Hlawatsch, F and F. Auger. Time Frequency Analysis: Concepts and Methods. 1 edition, Wiley-ISTE, 2008.

BME **** BIOMATERIALS AND BIOMECHANICS [4 0 0 4]

Introduction to Bio-materials: definition of biomaterials, requirements and its uses, classification of biomaterials, performance of biomaterials. **Metallic Biomaterials:** introduction, types - Stainless steel, Co-Cr alloys, Ti alloys, dental metals and other metals, corrosion behavior. **Ceramic Biomaterials:** introduction, Classification - Non-absorbable or relatively bioinert bio ceramics. Biodegradable or Resorbable ceramics. Bioactive or surface reactive ceramics. **Polymeric Biomaterials:** introduction, polymerization and its types, basic structure, classification solid state properties, discussion on different class of synthetic non-degradable polymers, Biopolymers, **Implantable Medical devices** Orthopedics, Cardiovascular Dentistry; **Testing of Biomaterials, Biomaterials for regenerative medicine**

Biomechanics: Anatomical movement descriptors, biomechanical principles of human movement, skeletal considerations for movement, muscular considerations for movement, fundamental concepts of gait, linear kinematics, angular kinematics, linear kinetics, angular kinetics.

SDL: Angular kinetics*

References:

1. Joseph D Bronzino, "The Biomedical Engineering Handbook", Third Edition, 2006, CRC press, USA.
2. Buddy D Ratner& Allen S Hoffman, "Biomaterials Science and Introduction to Materials in Medicine", Third Edition, 2012, Academic Press, Canada.
3. David Williams, Essentials Biomaterials Science, Cambridge university press, 2013
4. *Joseph Hamill and Kathleen M. Knutzen, Biomechanical Basis of Human Movement, Lippincott Williams & Wilkins, Third Edition, 2008, Philadelphia.
5. Ellen Kreighbaum, Katharine M Barthels, Biomechanics-A Qualitative Approach for studying Human Movement, Allyn and Bacon Publishers, Fourth Edition, 1995, USA.
6. Susan J. Hall, Basic Biomechanics, McGraw-Hill International Editions, Fifth Edition, 2006, Singapore.

BME **** HUMAN ANATOMY & PHYSIOLOGY [4 0 0 4]

PARTA: ANATOMY

Skeletal System: Types of bone, classification, Structure of bone, Blood supply, Cartilage: Type, Structure in brief, Joints: Classification, Structure of synovial joint, Major joints of the body. Muscle tissue: Types, Structure of skeletal muscle, Types of muscles, Brain: Parts, Brain stem, Ventricles, CSF, Meninges, Cranial nerves (names and functions only). Spinal cord: Gross features and structures, Spinal nerve, Nerve endings and receptors, Autonomic nervous system. Sensory system: Eye, Ear, Skin. Heart: Pericardium, Chambers, Blood supply Organs. Respiratory system: Parts, Trachea, Lungs. G I Tract: Parts, Stomach, Intestine, Liver, and Pancreas. Urinary system, Male and Female reproductive organs, and Endocrine glands.

References:

1. Sampath Madhyastha, "Manipal Manual of Anatomy", CBS Publishers & Distributors, Edition 3, 2016.

PART-B PHYSIOLOGY

Introductory lecture pertaining basic functional concept of the human body as a whole and contribution of the individual system. Hematology; Leverage system. Nerve action potential and its ionic basis. Body temperature regulation; Biophysical aspects of blood pressure (Bop) and its recording technique. Electrocardiograph and its gross normal features and alterations, Optics of the eye. Fundamental tonal analysis, determination of pitch, loudness and

quality of sound. Sensorium - general role of receptors as transducers, generation of potential in the receptors. Motor control of skilled voluntary movements: Mechanism of abnormal oscillatory movements Electroencephalogram and electrocorticogram.

References:

1. Charles E Tobin, "Manual of Human Dissection", McGraw Hill, Edition 4, 1961.
2. J Gibson, "Modern Physiology and Anatomy of Nurses", Black Well, 1981.
3. A J Vander, "J H Sherman, D S Luciano, Human Physiology", McGraw Hill, Edition 8, 2000.
4. Cyril A Keele, Eric Neil, Neil Norman Joels, "Samson's Wright's Applied Physiology", Oxford University Press, 1993.

HUM **** RESEARCH METHODOLOGY AND TECHNICAL COMMUNICATION

[1 0 3 2]

Mechanics of Research Methodology: Basic concepts: Types of research, Significance of research, Research framework, Case study method, Experimental method, Sources of data, Data collection using questionnaire, Interviewing, and experimentation. Research formulation: Components, selection and formulation of a research problem, Objectives of formulation, and Criteria of a good research problem. Research hypothesis: Criterion for hypothesis construction, Nature of hypothesis, need for having a working hypothesis, Characteristics and Types of hypothesis, Procedure for hypothesis testing, Sampling methods- Introduction to various sampling methods and their applications. Data Analysis: Sources of data, Collection of data, Measurement and scaling technique, and Different techniques of Data analysis. Thesis Writing and Journal Publication: thesis writing, journal and conference papers writing, IEEE and Harvard styles of referencing, Effective Presentation, Copyrights, and avoiding plagiarism.

References

1. Dr Ranjit Kumar, Research Methodology: A Step-by-Step Guide for Beginners, SAGE, 2005.
2. Geoffrey R. Marczyk, David DeMatteo & David Festinger, Essentials of Research Design and Methodology, John Wiley & Sons, 2004.
3. John W. Creswel, Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, SAGE, 2004
4. Suresh C. Sinha and Anil K. Dhiman, Research Methodology (2 Vols-Set), Vedam Books, 2006.
5. C. R. Kothari, Research Methodology: Methods and Techniques, New Age International Publisher, 2008.

BME **** BIOMEDICAL INSTRUMENTATION LAB [0 0 3 1]

Study of the characteristics of Capacitive pickup transducer, Inductive pickup transducer, pressure cell, Strain sensor, RTD transducer, Linear Variable Differential Transformer (LVDT), Hall effect transducer, LDR / Phototransistor and photodiode, load cell, thermocouple, DC serve motor control, voltage to frequency converter; Realization of a Pacemaker circuit and Instrumentation amplifier.

Demonstration: Study of Electrocardiograph and determining the cardiac vector; study of Audiometer and Air conduction thresholds testing; study of Blood Pressure meter, Defibrillator, Electrosurgical unit (ESU), Phonocardiograph and to visualize the heart sounds. Design and implementation of circuits with biomedical applications like QRS detector, Hearing aids, Digital thermometer etc.

References:

1. R.S. Khandpur, “Handbook of Biomedical Instrumentation”, Tata McGraw Hill, 1980.
2. Leslie Cromwell, “Bio Medical Instrumentation”, PHI, 1990.

BME **** BIOMEDICAL SIGNAL PROCESSING LAB [0 0 3 1]

Introduction to MATLAB. Generation of sequences: Unit sample, unit step, real/complex exponential, sinusoidal; LSI systems: Investigation of linearity & time-invariance, Computation of impulse response, Convolution, Stability; Computing and plotting the frequency response from the transfer function/unit-sample response; pole-zero plot from the transfer function. DFT: Illustration of circular shift of a sequence, circular time-shifting & circular convolution property, linear convolution via circular convolution; Computation of the DFT / FFT of a 1D signal. Implementation of FIR and IIR filters. Power spectrum estimation: Periodogram & Welch's method. ECG: QRS detection, extracting the RRI series and calculation of heart rate; the utility of Auto correlation & Cross correlation for template matching. ECG signal compression using Turning Point algorithm & DCT.

References:

1.A.V. Oppenheim, A.S. Willsky and I.T. Young, "Signals and Systems", Pearson Education India; 2nd Edition (2015).
2. Ronald W. Schafer, Alan V. Oppenheim, Discrete-Time Signal Processing, PEARSON 3rd Edition, 2014.
3. Rangaraj M Rangayyan, "Biomedical Signal Analysis - A case study", John Wiley and Sons,Singapore,2002.

BME **** BIOMATERIALS AND BIOMECHANICS LAB [0 0 3 1]

Preparation of hydroxyapatite bio ceramic particles, Characterization of hydroxyapatite particles by X-ray powder diffraction (XRD), Synthesis of ZnS nanoparticles by reverse micelle method, Synthesis of ZnS nanoparticles by reverse micelle method, Characterization of ZnS nanoparticles by UV Vis absorption spectroscopy, Preparation of alginate micro beads and encapsulation and release study of food colour, Characterization of Alginate beads by Fourier Transform Infrared Spectroscopy (FTIR), Thawing frozen cells and starting a new batch of culture, Sub culturing of confluent cells: splitting, counting and seeding cells, Freezing cells for long term storage in liquid nitrogen.
Modelling and Simulation using Opensim, Measuring Kinetic parameters using Force Plate, 2D motion data acquisition and analysis using Kinovea, Introduction to 3D motion analysis.

References:
1. William D. Callister, Jr., David G. Rethwisch, Materials Science and Engineering: An Introduction, 9th Edition, Wiley, 2014.
2. Buddy D. Ratner, Allan S. Hoffman, Frederick J. Schoen and Jack E. Lemons, *Biomaterial science- An introduction to Materials in medicine*, 3rd edition, Academic press, 2012.
3. T. Pradeep, A Textbook of Nanoscience and Nanotechnology, McGraw Hill Education, 1st edition, 2017.
4. Joseph Hamill and Kathleen M. Knutzen, Biomechanical Basis of Human Movement, Lippincott Williams & Wilkins, Third Edition, 2008, Philadelphia.
5. Ellen Kreighbaum, Katharine M Barthels, Biomechanics-A Qualitative Approach for studying Human Movement, Allyn and Bacon Publishers, Fourth Edition, 1995, USA.

SEMESTER 2

BME **** BASIC CLINICAL SCIENCES [4 0 0 4]

PART A PHYSIOTHERAPY

Physiology of pain and pain modulation, Pain reliving Modalities-Role of TENS, Interferential current therapy, Pain reliving modalities-II: Superficial Heating modalities, Short wave diathermy, Ultra sound, Laser, EMG, nerve conduction studies, Bio feedback and other diagnostic currents, Gait and gait analysis systems. Fitness, Cardiac and pulmonary rehabilitation- analysis and training instrumentation including Ergometer, Treadmill Evaluation methods: Concept of MMT, Dynamometer, Isokinetic, Esthisiometer, Goniometer, Instrumentation for different type of exercise: CPM, Hydrotherapy, Suspension. Introduction to Joint biomechanics with example of Knee and Hip Joint Orthotics and prosthesis, Practical Demonstration

References:

1. Gardiner M. Deena “The Principles of Exercise Therapy”, CBS Publishers & Distributors, 2007
2. Sheila Ed. Kitchen, Sarah Ed. Bazin “Clayton's Electrotherapy”10th edition, Bailliere Tindall, 1996
3. Susan B. O'Sullivan PT, EdD, Thomas J. Schmitz PT, PhD George Fulk PT, PhD F.A Davis, “Physical Rehabilitation”, 6th Edition, F A Davis Company, 2014

PART B SPEECH & HEARING

Audiometers, Middle ear analyzer, Evoked potentials, OAE, hearing aids, Cochlear implants, ALD, Hearing aid analyzer, Electro Glotto graphy, AAC, Introduction to speech assessment, DSP, Assessment of voice and fluency, Voice and fluency therapy assessment, Artificial larynx, Spirometry, Speech synthesis, Practical demonstration.

References:

1. Community based Rehabilitation, ISBNO 0-7020-1941-0, Saunders, London, 1997.
2. A Nenfeldt and A Albrigt, “Disability and Self- directed employment”, 1998.
3. Keele Cyril A, Eric Neil, “Samson Wright's applied Physiology”, oxford University Press, 1993.

PART C ORTHOPAEDICS

Bioengineering aspects of fracture management: Structure of bone-gross, Microscopic biochemical fractures: Types, Mechanism of injury, Normal Healing of Fractures, Treatment of fractures: General principles, The concepts of load bearing, load sharing and stress shielding by implants, Piezo electricity and electrical stimulation for bone healing, Bioengineering aspects of joint diseases, Structure of joints: Fibrous, Cartilaginous, Synovial, Lubrication of joints and the functions of articular cartilage, Degeneration of cartilage, Degenerative arthritis and Rheumatoid arthritis, Joint replacement, hip, knee, shoulder, small joints. Biomaterials: Gait analysis, Orthotics, Principles of tendon transfer, Bioengineering principles of amputation and prosthetics, Upper limb prosthesis, Lower limb prosthesis.

References:

1. Victor H Frankel and Margareta Nordin, “Basic Biomechanics of the skeletal system”. Lea and Febiger, 1980.
2. M. Dena Gardiner, “The principles of exercise therapy”, CBS press, Edition 4, 1985.

PART D RADIOLOGY

X-ray tube, Target material, focal spot, size, shape of filament rotating anode, cooling of target tube, Interaction of X-ray with matter, Use of filters, scattered rays, quality of X-rays, HVL, CONES, Grids, Photographic effects on X-ray film, density, contrast, distortion, Speed of X-ray film, Fluorescent & Intensifying screen, Computed Tomography; Image Intensifier, Digital Subtraction Angiography, Radiation hazards & protective measures; X-Ray Exposure Parameters; Ultrasonography, Principles of Magnetic Resonance Imaging; Brachy Therapy.

References:

1. Thomas S. Curry, James E. Dowdey, Robert C. Murray, "Christensen's Physics of Diagnostic Radiology", Illustrated Edition, Lippincott Williams and Wilkins, 1990.

2. Joseph Selman", The fundamentals of Imaging Physics and Radiobiology", 9th Edition, Charles C. Thomas, 2000.

3. Penelope Allisy-Roberts, Jerry R Williams, "Farr's Physics of Medical Imaging", Illustrated Edition, Elsevier Health Sciences, 2007.

BME **** MEDICAL IMAGE PROCESSING [4 0 0 4]

Signals & systems in 1D & 2D; 2D DFT and its computation. Image perception the human vision system, psycho-visual experiments, monochrome vision model, temporal properties. Image compression the discrete cosine transforms (DCT), properties, computation, practical compression algorithm. Image Enhancement: Point operations and Spatial filtering: linear filters & the median filter. Connected-component labeling. Medical Imaging: Imaging modalities; Computed tomography (CT): mathematical basis, the Radon transform & the central slice theorem; Image reconstruction from projections: The Direct Fourier Method, convolution back-projection (CBP), reconstruction from fan-beam projections; X-rays: utility, generation and detection; X-ray CT systems. Emission CT: principles, Positron emission tomography (PET); Magnetic resonance imaging: Principles of data-generation, resolving the tissues, resolving the spatial locations. Edge detection; Colour-image processing: Fundamentals, Colour Models, Biomedical Engineering Applications.

References:

1. R.C Gonzalez and R.E. Woods, Digital Image Processing, 2nd Ed., Pearson Education Inc., Eighth Indian Reprint, 2002.
2. Jae S. Lim, Two-dimensional Signal and Image Processing, Prentice-Hall, Englewood Cliffs, New Jersey, 1990.
3. A. K. Jain, Fundamentals of Digital Image Processing, Prentice-Hall, 1989, Fourth Indian Reprint.
4. A.C. Kak and M. Slaney, Principles of Computerized Tomographic Imaging, SIAM's Classics in Applied Mathematics, Philadelphia, SIAM, 2001.
5. Kline Jacob, Handbook of Biomedical Engineering, Academic Press, 1988.

BME **** BIOMEDICAL RESEARCH LAB [0 0 3 1]

Student is assigned under a faculty for specific research topics like Biomedical Signal Processing, Biomaterials, Image processing, Tissue Engineering, Biomedical Instrumentation and many other topics related to healthcare. Students are evaluated based on synopsis presentation, mid-term and final evaluation along with report. The evaluation is conducted by the assigned Faculty in consultation with program coordinator and committee members.

BME **** MEDICAL IMAGE PROCESSING LAB [0 0 3 1]

Image Processing - Display and simple manipulations: flipping, rotation, and scaling; Decimation & interpolation; Effects of thresholding; Bit-plane mapping. Histogram of an image; Contrast enhancement: Application of manually specified transforms, Contrast Stretching; Computation of the 2D DFT, 2D FFT. Image Filtering - Spatial domain techniques: Neighborhood averaging

Median Filtering; Frequency-domain techniques: High pass and low pass filtering. Edge detection: Sobel, Prewitt & Robert's operators. Image Compression using DCT. The Radon Transform (RT): The RT of the Shepp-Logan Phantom; The inverse RT and image reconstruction from projections; Effects of the number of projections. Implementation of CBP algorithm, Hough transform & Geometric transformations.

References:

1. Rafael C. Gonzalez, Richard Eugene Woods, Digital Image Processing using MATLAB, 2nd Edition, Tata McGraw-Hill Education 2010.
2. A.K. Jain, *Fundamentals of Digital Image Processing*, Prentice-Hall, 1989, Fourth Indian Reprint.

SECOND YEAR

BME **** PROJECT WORK [0 0 0 25]

Students are required to undertake innovative and research-oriented projects, which not only reflect their knowledge gained in the previous two semesters but also reflects additional knowledge gained from their own effort. The project work can be carried out in the institution/ industry/ research laboratory or any other competent institutions. The duration of project work should be a minimum of 36 weeks. There will be a mid-term evaluation of the project work done after about 18 weeks. An interim project report is to be submitted to the department during the mid-term evaluation. Each student has to submit to the department a project report in prescribed format after completing the work. The final evaluation and viva-voice will be after submission of the report. Each student has to make a presentation on the work carried out, before the departmental committee for project evaluation. The mid-term & end semester evaluation will be done by the departmental committee including the guides.

PROGRAM ELECTIVES

BME **** NANOMATERIALS & CHARACTERIZATION TECHNIQUES

[4 0 0 4]

Introduction nanotechnology: Nanomaterials- classifications, synthesis methods, surface functionalization of nanoparticles, nanocomposites. Properties of nanomaterials: - mechanical properties, optical properties, magnetic properties. Characterization tools for nanomaterials and Nano systems- structural and chemical characterization techniques. Physical and chemical characterization of Nanomaterials: Transmission electron microscope (TEM),

scanning electron microscope (SEM), scanning tunneling microscope (STM), atomic force microscope (AFM), X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FT-IR), dynamic light scattering (DLS). Thermal characterization of nanomaterials: Thermogravimetric analysis (TGA), differential thermal analysis (DTA), differential scanning calorimetry (DSC). Raman spectroscopy and ultraviolet spectroscopy. Biomedical applications of nanotechnology: Imaging, Drug delivery systems, Therapeutics, Nanotechnology for biosensors, tissue engineering

SDL: Properties of nanomaterials: - mechanical properties, optical properties, Source: NPTEL, Course Name: Nano structured materials-synthesis, properties, self-assembly and applications Instructor: Prof. A.K. Ganguli, IIT Delhi, Optical properties 1, Optical properties 2, Mechanical properties; Duration: 3Hr

References

1. Guozhong Cao, *Nanostructures and nanomaterials Synthesis*, Imperial Press 2011.

G.A. Ozin and A.C. Arsenault, *Nanochemistry: A chemical approach to Nanomaterials*, Royal Society of Chemistry, 2005.

T. Pradeep, *A Textbook of Nanoscience and Nanotechnology*, McGraw Hill Education, 1st edition, 2017.

P. M. Ajayan, L. S. Schadler, P. V. Braun, Nanocomposite Science and Technology, Wiley-VCH; 1 edition.

BME **** CELL CULTURE TECHNIQUES AND STEM CELL BIOLOGY [4 0 0 4]

The goal of this course is to impart students with the knowledge of cell culture techniques and provide insights into stem cell biology. Students taking this course would get a detailed understanding of techniques and protocols related to animal cell cultures. Apart from cell culture techniques, students also learn the fundamental of developmental and stem cell biology. This course will be helpful for students who want to pursue a career in basic biomedical research especially in areas like tissue engineering, biomaterials, Nano biotechnology and regenerative medicine

References

1. The culture of animal cells: A manual of basic technique and specialised applications (Seventh edition). Ian Freshney Wiley, ISBN-13: 978-0879696733.
2. Essentials of Stem Cell Biology (Third Edition). Robert Lanza and Anthony Atala, Elsevier, ISBN: 978-0-12-409503-8.
3. Stem Cell Biology, Daniel R. Marshak, Richard Lavenham Gardner, David Gottlieb, Cold spring harbour laboratory press. ISBN-13: 978-0471739913.

BME **** EMBEDDED SYSTEMS [4 0 0 4]

Introduction to Embedded systems, processor and memory organization, Devices and buses for device networks, Device drivers and interrupts servicing mechanisms. Programming concepts, and embedded programming in C. Real Time Operating systems, and Serial and Parallel Buses. PIC Architecture and Instruction set, MPASM assembler and its usage, Analog-to-Digital conversion, UART. Medical Embedded systems.

SDL: Memory and I/O interfacing, GPIO of STM 32 microcontroller*

References:

1. *Raj Kamal, "Embedded systems Architecture, programming and Design" TaTa McGraw Hill, 4th Reprint 2008.
2. Frank Vahid and Tony Givargis, "Embedded system Design a Unified Hardware/Software Introduction" Wiley India Pvt. Ltd.
3. Tim Wilmshurst, "An Introduction to the design of Small-Scale Embedded Systems" Palgrave, New York 2003.
4. John B. Peatman, "Design with PIC Microcontrollers", first Edition, Pearson Education.

BME **** EXPERIMENTAL TECHNIQUES IN BIOMEDICAL RESEARCH [4 0 0 4]

The objective of this course is to impart knowledge of various experimental techniques and methodologies related to the field of biomedical research. The course is intended for students who are interested in pursuing biomedical research associated with areas of biomaterials, drug delivery, tissue engineering, material sciences and bio nanotechnology. The course structure is divided into three major parts, of which the first- and second-part deals with experimental techniques employed in the characterisation of materials and biological entities. The final section of this course is meant to address questions such as how experiments are designed and to analyse experimental data critically. At the end of the course, students who completed the course would be confident in interpreting experimental data that is published in biomedical journals.

Reference:

1. Principles and Techniques of Biochemistry and Molecular Biology. Keith Wilson, John Walker, 7th edition. Cambridge University Press, ISBN 978-0-521-51635-8.
2. A Guide to Methods in the Biomedical Sciences. Ronald B. Corley, Springer.

BME **** MACHINE LEARNING [4 0 0 4]

Basics of machine Learning, principle and Applications in healthcare, machine Learning Foundations, learning methods: Basic concepts in machine learning and an example. Design cycle for developing machine learning application. Perspectives and issues in machine learning. Linear models and regression models, Discriminate Functions, Single layer neural network, linear reparability, general gradient descent, perception learning algorithm, multi-layer perception: back propagation learning, Support Vector Machines (SVM), SVM for classification. Introduction to Deep learning networks. Clustering, Independent components analysis, Decision Tree learning, Reinforcement learning control, evolutionary optimization techniques, statistical machine learning, machine learning in Healthcare applications.

References:

1. Tom M. Mitchell, “Machine Learning”, McGraw-Hill Education, 2013.
2. Richard o. Duda, Peter E. Hart and David G. Stork, “Pattern Classification”, John Wiley & Sons Inc., 2001.
3. Ethem Alpaydin, “Introduction to Machine Learning”, Prentice Hall of India, 2005.
4. Christopher Bishop, “Pattern Recognition and Machine Learning”, Springer; 2nd, 2011.
5. Saeid Sanei, and Jonathon A Chambers, “EEG Signal Processing”, John Wiley and Sons, 2007.

BME **** PATTERN RECOGNITION [4 0 0 4]

Machine perception, Pattern recognition (PR) system, Statistical decision theory, patterns and feature extractions, Applications of Pattern Recognition, The Design Cycle, Training and learning in PR system, Pattern recognition approaches, Statistical decision making: Bayes theorem, multiple features, conditionally independent features, Decision boundaries, Unequal costs of error, Estimation of error rates, leaving one-out technique, Characteristic curves, problems, Syntactic Pattern Recognition: Syntactic pattern recognition overview, quantifying structure in pattern description and recognition, Grammar based approach and applications, Supervised Learning (Training) using parametric and non-parametric approaches, Histograms, nearest neighbor classification techniques, Unsupervised learning and clustering, Artificial Neural Networks: Introduction, Nets without and with Hidden layers, Hebbs net, Perceptron algorithm, Back propagation algorithm and Applications.

References:

1. Richchard O Duda, Peter E. Hart, David G.Strok, “Pattern Classification”, Wiley edition, 2001.
2. Earl Gose, Richard, Johnson baugh and Steve Jost, “Pattern recognition and Image analysis”, Prentice Hall, 2002.
3. Schalkoff Robert J, “Pattern recognition”, John Wiley,1992.
4. E.S.Gelsema and L.N. Kanal, "Pattern Recognition and Artificial Intelligence", Elseveir Science, 1998

BME **** TISSUE ENGINEERING [4 0 0 4]

Introduction: Basic definition, Structural and organization of tissues: epithelial, connective tissues; Sterilization process: Introduction, different sterilization methods: physical, chemicals; applications in terms of tissue engineering, Morphogenesis, Tissue homeostasis, Cellular signaling: introduction, cellular signaling in skin, bone cartilage biology; understanding and implementing principles of cell signaling in tissue engineering; Stem cell: introduction, types, embryonic and adult stem cells, recent advances and future perspective, Cell culture, cell source, cell types, various aspects; cell-cell interaction, Molecular biology aspect, Scaffold: polymer, natural polymer for tissue engineering, degradable materials, various type of scaffold, cell –matrix interaction, micro and nanofabrication techniques in scaffold fabrication and their importance in tissue regeneration, Engineering tissues for replacing bone, cartilage

Reference Books:

1.Satya Prakash, D.S. Tim, Stem cell bioengineering and tissue engineering microenvironment, World Scientific, 2012 ISBN: 139782837882

2. Endarle, Blanchard & Bronzino, Introduction to Biomedical Engineering, Academic press, 1998

3. Frontiers in tissue engineering C.W. Patrick Jr., A. G. Mikos, L.V. Mcintire, Pergamon, Elsevier, 1998 ISBN: 008042689 1

4. B. O Palsson, Sangeeta N. Bhatia, Tissue Engineering, Edition 1, 2004 Pearson, New Jersey, USA, ISBN 0-13-041696-7

5. S. Li et al, stem cell and Tissue Engineering, World Scientific, 2011, ISBN 13 978-981-4317-05-4.

BME **** INTERNET OF MEDICAL THINGS [4 0 0 4]

Internet of Things: IoT Protocols, Logical Design, Enabling Technologies, Levels, IoT vs M2M, Design Methodology, Domain Specific Applications, Wireless Sensor Networks, Protocol Standards, Issues, Routing, Applications, Protocols: Bluetooth, Introduction, Protocol Stack, RF Classes, Radio Technologies, Service Discovery, Device Discovery, Profiles, Security (Discovering Bluetooth), Hardware, Zigbee, Frequency, Channels, Topology, Zigbee Protocol Stack, PHY, MAC Layer, Working, Frame Structure, Beacon , Non-Beacon Communication, Zigbee PDU , Zigbee Hardware, API Mode and AT mode communication, Internet Protocol, Introduction to IPv4 and IPv6, IPv4 Headers, Ipv6 Headers, 6LoWPAN, 6LoWPAN architecture: simple, extended and ad-hoc networks. Issues in determining IPv6 links in LLNs and illustration of the undetermined link addressing model. IPv6 addressing in 6LoWPAN.Sockets: Introduction to Sockets, Client Server Architecture, Unix Sockets, PORTS, Python APIs of Sockets, TCP socket programming using Python, UDP, RAW packets python programming. Healthcare applications.

SDL: Domain specific applications, Healthcare applications*

References:

1. Arshdeep Bhaga, Vijay Madishetti, “Internet of things: A hands on Approach”, Universities Press, ISBN:978172719547
2. Robert Faludi,” Building Wireless Sensor Networks”, Orielly, 2012
3. Jean-Philippe Vasseur, Adam Dunkels,"Interconnecting Smart Objects with IP: The Next Internet", Morgan Kaufmann Publishers,2010, ISBN:0123751659 9780123751652
4. Marco Schwartz, “Internet of Things with the Arduino Yun”, Packt Publishing,2014
5. Charalampos Doukas,"Building Internet of Things with the Arduino: Volume 1”, Create Space Independent Publishing Platform,2012
6. Houda Labiod, Hossam Afifi, Costantino De Santis, “Wi-Fi, Bluetooth, Zigbee and WiMAX”, Springer Publications
7. Madhushree Ganguli, “Getting started with Bluetooth”, Premier Press, 2002, ISBN 1931841837, 9781931841832.

BME ****AUGMENTED REALITY AND VIRTUAL REALITY [4 0 0 4]

Introduction to augmented reality (AR) and Virtual Reality (VR) interfaces. **Virtual Reality Module:** Definition and goals of Extended Reality, historical perspective, different applications of VR (news, sports, entertainment, surgery, training etc.), Psychology of VR: Place illusion, plausibility illusion, embodiment illusion, Graphics in VR: Transformations, 3D audio, Tracking in VR (Tilting/Yawing/SfM), general outline of content creation in VR. Interaction in VR: Natural Interaction, Magic/Active/Passive Interaction, Teleportation in VR, Virtual Navigation, redirected walking, walk-in-place, Interacting with objects in VR, hyper-natural interaction, evaluation metrics, physics-based interaction, state machines, User interfaces in VR: Abstract Interfaces, Diegetic/Non-diegetic interfaces, gestural interaction, issues in VR interaction, User Interfaces in Unity3D: Unity gesture plugin, Bespoke VR, Virtual Characters in VR, Body Animation in VR, Facial Animation, Social VR. **Augmented Reality Module:** Introduction to Augmented Reality, introduction to augmented reality frameworks (wikitude, ARCore, ARToolkit), Building AR in mobiles: Building an Android App in Unity3D, building an iOS app in Unity3D, Building AR experiences to Android/iOS, 2D image recognition and tracking (Camera representation, marker detection, post estimation), single image training and detection, shadows, occlusion, example projects, multiple image training and detection, tracking multiple markers, handling multiple trackers, GPS and compass integration, 3D Object Recognition and Tracking: Marker training, 3D object marker with occlusion, 3D scene recognition, Markerless Tracking: Getting started with instant tracking, adding physics simulation to a markerless environment, hiding and showing augmented objects

References:

1. Grigore C. Burdea, Philippe Coiffet, Virtual Reality Technology, Wiley 2016
2. Alan B. Craig, Understanding Augmented Reality, Concepts and Applications, Morgan Kaufmann, 2013.
3. Alan Craig, William Sherman and Jeffrey Will, Developing Virtual Reality Applications, Foundations of Effective Design, Morgan Kaufmann, 2009.
4. John Vince, "Virtual Reality Systems ", Pearson Education Asia, 2007.
5. Anand R., "Augmented and Virtual Reality", Khanna Publishing House, Delhi.
6. Peter Shirley, Michael Ashikhmin, and Steve Marschner, Fundamentals of Computer Graphics, A K Peters/CRC Press; 3rd edition, 2009.

BME ****HEALTH INFORMATION SYSTEMS [4 0 0 4]

Healthcare data, information & knowledge: Health information exchange; Health care data Standards & Quality; Technologies that support health informatics; Clinical and administrative application components; Different modules; Clinical data warehouses. Electronic health records (EHR): Key components; Computerized physician order entry; Clinical decision support system; Practice Management System & EHR; Electronic health record standards for India. Web-enabled technology applications: Telemedicine; Picture Archiving & Communication System; Mobile health; Consumer health informatics; Patient web portals: Personal Health Records; Public Health Informatics

Health information system adoption: Organizing information technology services; System development life cycle; System acquisition process; System implementation; System support and evaluation; Information technology alignment and strategic planning; Security of electronic data and networks: Health information Privacy; Health informatics Ethics; Transferring ethical responsibility; Health information Security; HIPAA security rules; Basic security Principles.

References

1. Hoyt, R.E., & Yoshihashi, A.K. (2014). Health Informatics: Practical Guide for Healthcare and Information Technology Professionals, (6th ed). Florida, USA: Informatics Education.
2. Wager, K.A., Lee, F.W., & Glaser, J.P. (2013). Health Care Information Systems: A Practical Approach for Health Care Management, (3rd ed). San Francisco, CA: Jossey-Bass

BME ****DIGITAL PATHOLOGY AND DIGITAL IMAGING [4 0 0 4]

Introduction to Pathology and Digital pathology; Radiology Vs. Digital pathology; Basics of Hematopathology, Histopathology; Benefits of digital pathology over the conventional diagnosis approach; Glass slides Vs. Digital slides; Applications of digital pathology over standard pathology practices; Telepathology applications; Digital pathology image capture - Digital microscope, Digital slide scanners; Process of blood smear slide preparation, blood smear image capture, and analysis; Demonstration on Blood slide preparation, Peripheral blood smear image capture using a digital microscope; Whole Slide Imaging (WSI) - major challenges to be addressed; The pyramidal format used in WSI and its significance; Standards for digital pathology and WSI - Image file formats, Compression schemes, Role of DICOM; Demonstration on WSI system; Digital pathology image analysis – Current technology and challenges, Case Studies; Applications of Machine/Deep learning in Digital pathology, Case Studies.

SDL: Telepathology*

References:

1. *Keith J. Kaplan, Luigi K.F. Rao, “Digital Pathology: Historical Perspectives, Current Concepts & Future Applications”, 1st ed. 2016 springer, ISBN-13: 978-3319203782, ISBN-10: 9783319203782
2. Yves Sucaet, Wim Waelput, “Digital Pathology, 2014 Edition, Springer
3. *Liron Pantanowitz and Anil V Parwani, “Digital Pathology”, American Society of Clinical Pathologists Press, ISBN-10: 0891896104, ISBN-13: 978-0891896104

Medical Imaging modalities: X-ray systems- generation, conventional detectors and flat panel detectors, diagnostic X-rays; Computed tomography: Principles of CT, data acquisition system, Different generations of CT geometries, image reconstruction algorithms; Positron Emission Tomography (PET): properties of radionuclides, Radionuclide production; principle of PET, PET detectors: Scintillation detectors, Radionuclide imaging systems; MRI: Principle of MRI, Longitudinal & transverse magnetization, T1 and T2 weighted images, MRI system; Ultrasound: Principles of ultrasonography, modes of operation: A-mode, B-mode, M-mode scanning, processing and display of ultrasound images; advancement in ultrasound imaging; Thermography: principles and applications; Data security and standards in healthcare.

SDL: Positron emission tomography*

1. *Smith NB, Webb A, “Introduction to medical imaging: physics, engineering and clinical applications”, Cambridge university press; 2011, ISBN: 9781139492041, 1139492047.

BME ****INNOVATION AND ENTREPRENERSHIP [4-0-0-4]

The Entrepreneurial Mind-Set, Startup Eco system, Corporate Entrepreneurship, Generating And Exploiting New Entries, Creativity and The Business Idea, Identifying and Analyzing Opportunities (Domestic and International), Protecting The Idea And Other Legal Issues For The Entrepreneur, The Business Plan, The Marketing Plan, The Organizational Plan, The Financial Plan, Sources of Capital, Informal Risk Capital, Venture Capital, Going Public, Strategies For Growth , Managing The Implications of Growth, Accessing Resources For Growth From External Sources, Succession Planning.

References

1. Hisrich, R D., Peters, M P, Shepard D A, Sinha. S. Entreprenuership (11e), McGraw-Hill Special Indian Edition, 2020
2. Murray, E L., Neck, H M., Neck, C P. Entrepreneurship: The Practice and Mindset (2 edition) Sage Publication
3. Norman S and Cornwall J Essentials of Entrepreneurship and Small Business Management, Pearson Publication
4. Robert D Hisrich, M P Peters, D A Shepherd, Entrepreneurship, McGraw Hill, 10th edition (2017)
5. Rajeev Roy, Entrepreneurship, Oxford Higher Education, 2nd edition (2011)
6. David H Holt, Entrepreneurship: New Venture Creation, Prentice Hall (2019)

BME ****BIOMETRICS FOR HEALTHCARE SYSYEM [4-0-0-4]

Basic image operations, Interpolation, Special filters, enhancement filter, Edge detection, thresholding, localization. Introduction of biometric traits and its aim, Biometric system, authentication, physiological and behavioral properties, Identification and verification, Threshold, Score distribution, FAR and FRR, System design issues - Expected overall error, EER, ROC curve, DET curve, FAR/FRR curve. Existing Biometric Technologies: Fingerprints, Face, Iris, Hand Geometry, Ear, Voice, Retina, Gait. Introduction to physiological and behavioral biometrics in hospitals or care units, Biometric authentication based on ECG, EMG, and Phonocardiograph (PCG) signals. Multimodal identification and Verification system, normalization strategy, Fusion methods, Biometric system security. Face and ECG Based Multimodal Biometric Authentication.

References:

1. Girija Chetty and Jucheng Yang, Advanced Biometric Technologies, InTech, 2011.
2. Jain, A.K., Ross, A., Nandakumar, K. Introduction to Biometrics. Springer; 2011 edition.
3. David Zhang, Fengxi Song, Zhizhen Liang, Yong Xu, Advanced Pattern Recognition Technologies with Applications to Biometrics (Premier Reference Source), Medical Information Science Reference; 1st edition, 2009.
4. Ruud M. Bolle, Sharath Pankanti, Nalini K. Ratha, Andrew W. Senior, Jonathan H. Connell Guide to Biometrics, By, Springer, 2009.
5. Duda, Richard, Peter Hart, and David Stork. *Pattern Classification*. 2nd ed. New York, NY: Wiley-Interscience, 2007.
6. Rafael C. Gonzalez, Richard Eugene Woods, Digital Image Processing using MATLAB, 2nd Edition, Tata McGraw-Hill Education 2010.

OPEN ELECTIVE

BME **** PHYSIOLOGICAL CONTROL SYSTEMS [3 0 0 3]

Introduction to Technological Control System, Transfer functions, Mathematical Approaches, System Stability, Feedback Concept and Stability Analysis. Introduction to Biological Control System, similarities and differences, Transfer of substances between compartments, Biological receptors, characteristics, Regulation of acid-base balance, Endocrine Control, Regulation of Extra Cellular Water and Electrolyte. Introduction to Various Process Controls like Cardiac Rate, Blood Pressure, Respiratory Rate and Blood Glucose Regulation. Modelling of Human Thermal Regulatory System, Parameters Involved, Control System Models etc. Biochemistry of Digestion. Type of Heat Loss from the Body, Model of Heat Transfer between Subsystems of Human Body like Skin, Core, etc, Respiratory control system, Modelling of O2 Uptake, Mass Balancing by Lungs, Gas Transport Mechanism of Lungs, O2 and CO2 Transport in Blood and Tissue. Introduction to Eye Tracking and Control. Cardio Vascular Control system, pupil control system, MATLAB applications in control systems.

References:

1. H.T. Milhorn, “The Applications of Control Theory to Physiological System”, W.B. Saunders, 1966.
2. J. H... Milsum, Biological Control System Analysis, McGraw Hill, 1966.
3. B.C. Kuo, Automatic Control System, 9th edition, Prentice Hall, 2009.

BME****MEDICAL DATA INFORMATICS [3 0 0 3]

Introduction to biomedical data, medical data acquisition, storage, and use, decision making: probabilistic clinical reasoning, cognitive science, computer architectures for health care and biomedicine, standards in biomedical informatics, biomedical imaging informatics, ethics and biomedical and health informatics: users, standards, and outcomes.- evaluation of biomedical and health information resources, electronic health record system, the health information infrastructure, management of information in health care organization, patient-centered care systems, public health informatics, consumer health informatics and personal health records, tele-health, patient monitoring systems, imaging systems in radiology, information retrieval and digital libraries, clinical decision-support systems, computers in health care education, bioinformatics, clinical research informatics, health information technology policy, the future of informatics in biomedicine.

Reference:

1. Shortliffe E, “Biomedical Informatics Computer Applications in Health Care and Biomedicine”, Springer, 5th Ed 2021.
2. Alain Venot, Anitha B., Catherine Q., “Medical Informatics”, E-Health, Springer, 2021