M.Tech Curriculum 2023-24

Department of Applied Science

(NEP based Curriculum)

Guidelines for M. Tech& Duel degree M. Tech-PhD 2023-24

PC- Programme Core, PE- Programme Elective, ES- Engineering Science, BS- Basic Science, OE- Open Elective, HM- Humanities and Management, MR- Minor, HR- Honor, AC- Audit Course

L-T-P (hr)

Lecture (L): 1 Credit = 1 hr/ week, Tutorial (T): 1 Credit = 1hr/week, Practical (P): 1 credit = 2 hr/week

The credits for all courses are given in LTP format. L stands for Lecture, T for Tutorial, P for Practice/Practical. L=3 signifies 3 hours of Lectures per week, T=1 signifies 1 hour of Tutorial per week, an P=1 corresponds to 2 hours Practice/Practical per week. For M. Tech. students, T and P need not be explicitly mentioned in the Time Table. The Practice/Practical component of the course could also be a Term paper or Term Paper along with the lab. The discretion is left to the Teacher teaching the course.

The dual degree M.Tech.-Ph.D. Programme has been kept reserved. This is in tune with the spirit of NEP 2020. It is envisaged with a target towards research leading to a PhD programme with a minimum duration of 04 years, and with a possible exit for the award of MTech degree and/or PG Diploma after securing required credits.

Please refer to the M.Tech. and Ph.D. Ordinance for the other details of the M. Tech. and Ph.D. programs that is available at the following link: https://aaa.iiita.ac.in/

The AS Department is offering the following specializations in each group:

M. Tech Biomedical Engineering

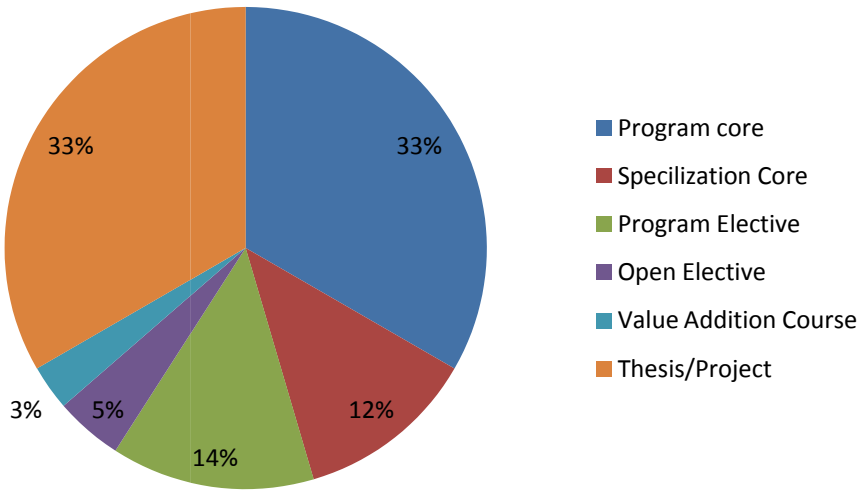
The M. Tech Biomedical Engineering program at IIIT-Allahabad is designed to provide students with a comprehensive understanding of the interdisciplinary field that combines principles of engineering, medicine, and biology. The mission of the Biomedical Engineering course at IIIT-A is to build up clinically adaptable solutions for human health by educating the next generation of biomedical engineers, cultivating leaders, and nurturing the amalgamation of science, engineering, and medicine in a discovery-focused environment. The main educational objective is to offer a systematic training in the fundamentals of engineering science, design, and biology. The curriculum is planned to endow with concepts essential to understanding living systems from the molecular and cellular levels. The curriculum further incorporates principles of straight up integration, leading to the choice of a technical area (biomedical imaging and instrumentation, cellular engineering, computational biomedical engineering, or biomechanics), and culminates in a biomedical device design experience. With state-of-the- art facilities and a team of experienced faculty members, IIIT-Allahabad is committed to offering students a stimulating and nurturing learning environment.

Total Credit Distribution

Semester	Semester I	Semester II	Summer Semester	Semester III	Semester IV	Total Credits
M. Tech	18	19	0	17	12	66
PG Diploma	18	19	5	-	-	42

M. Tech BME, Credit Distribution

M. Tech BI		I	II	III	IV	Total Credits	
1.	Program core	8	14			22	33%
2.	Specialization Core	8				8	12%
3.	Program Elective		3	6		9	14%
4.	Open Elective			3		3	5%
5.	Value Addition Course		2			2	3%
6.	Thesis/Project		2	8	12	22	33%



Indian Institute of Information Technology - Allahabad

Deoghat, Jhalwa- 211015, Prayagraj, Uttar Pradesh

Department of Applied Sciences

Table 1: First Semester

Hard-Core Subjects

Sl. No.	Course Name	Code	Type	Credit	Hours L-T-P-S
1.	Biomedical Circuits and Instrumentation	PC-AS-BCI501	PCC	4	3–0–2-0
2.	Biomechanics	PC-AS-BOM502	PCC	4	3–0–2-0
3.	Research Methodology & IPR	PC-AS-RMA503	ELC	2	2–0–0-0
			Total Credit:	**10**	12 Hrs./week

Soft-Core Subjects (Choose a single basket)

Basket 1: Medical/B.Pharma. /Pharmacology/Biotechnology/M.Sc. in Biology or Life sciences

Sl. No.	Course Name	Code	Type	Credit	Hours L-T-P-S
1.	Biosignal Processing	ES-AS-BOP501	PCC	4	3–0–2-0
2.	Biomath and Biostatistics	BS-AS-BMB501	PCC	4	3–0–2-0
			Total Credit:	**8**	10 Hrs./week

Basket 2: Engineering/Technology/Instrumentation/Electronics/IT/CS/Physics/Applied Physics

Sl. No.	Course Name	Code	Type	Credit	Hours L-T-P-S
1.	Molecular Biology	ES-AS-MBO502	PCC	4	3–0–2-0
2.	Anatomy & Physiology	ES-AS-APH503	PCC	4	3–0–2-0
			Total Credit:	**8**	10 Hrs./week

Basket 3: Applied Chemistry/Applied Math

Sl. No.	Course Name	Code	Type	Credit	Hours L-T-P-S
1.	Anatomy & Physiology	ES-AS-APH503	PCC	4	3–0–2-0
2.	Biosignal Processing	ES-AS-BOP501	PCC	4	3–0–2-0
			Total Credit:	**8**	10 Hrs./week

Table 2: Second Semester

Sl. No.	Course Name	Code	Type	Credit	Hours L-T-P-S
1.	Advanced Medical Instrumentation	PC-AS-AMI504	PCC	4	3–0–2-0
2.	Biomedical Imaging	PC-AS-BIM505	PCC	4	3–0–2-0
3.	Medical Sensors and Actuators	PC-AS-MSA506	PCC	4	3–0–2-0
4.	Elective I	PE-AS-XXX501	PEC	3	3–0–0-0
5.	Mini Project	PC-AS-MPJ507	ELC	2	0–0–4-0
6.	HSMC	HM-AS-RMI501	VEC	2	2–0–0-0
			Total Credi :	**19**	24 Hrs./week

EXIT: *After the end of second Semester, after clearing all the papers, the M. Tech student may be eligible for PG Diploma in Biomedical Engineering. However, these students have to secure* ***additional 5 credits*** *from summer semester for awarding PG diploma, which is mandatory. For regular M. Tech students there is no need of summer semester.*

Table 3: Summer Semester (for **PG-Diploma**)

Sl. No.	Course Name	Code	Type	Credit	Hours L-T-P-S
1.	Summer Project	PC-AS-SPJ508	ELC	2	0–0–4-0
2.	Medical Instrumentation Course/NP EL	PC-AS-MIC509	PCC	3	3–0–0-0
			Total Credit:	**5**	7 Hrs./week

Table 4: Third Semester

Sl. No.	Course Name	Code	Type	Credit	Hours L-T-P-S
1.	Elective II	PE-AS-XXX502	PEC	3	3–0–0-0
2.	Elective III	PE-AS-XXX503	PEC	3	3–0–0-0
3.	Open Electives	OE-XX-xxx501	OE	3	3–0–0-0
4.	Major Project	PC-AS-MPJ509	ELC	8	0–0–16-0
			Total Credi :	**17**	25 Hrs./week

Table 5: Fourth Semester

Sl. No.	Course Name	Code	Type	Credit	Hours L-T-P-S
1.	M. Tech Thesis	PC-MTH510	ELC	12	0–0–24-0
			Total Credi :	**12**	24 Hrs./week

Table 6: List of Electives (for elective I, II and III)

Sl. No.	Course Name	Code	Type	Credit	Hours L-T-P-S
1.	Bioelectrics	PE-AS-BIE501	PEC	3	3–0–0-0
2.	Biomaterials and Tissue Engineering	PE-AS-BTE502	PEC	3	3–0–0-0
3.	Medical Image Processing	PE-AS-MIP503	PEC	3	3–0–0-0
4.	Nanobiotechnology and Nanoinformatics	PE-AS-NBN504	PEC	3	3–0–0-0
5.	Bio-MEMs	PE-AS-BIM505	PEC	3	3–0–0-0
6.	Artificial Organs and Implants	PE-AS-AOI506	PEC	3	3–0–0-0
7.	Engineering Processes in Biological Systems	PE-AS-EPB507	PEC	3	3–0–0-0
8.	Soft Computing Tools for Biomedical Engineering	PE-AS-SCT508	PEC	3	3–0–0-0
9.	Computational Methods for Biomedical Engineers	PE-AS-CMB509	PEC	3	3–0–0-0
1	Modeling of Biomedical Engineering Systems	PE-AS-MBE510	PEC	3	3–0–0-0
1	Telemedicine	PE-AS-TEM511	PEC	3	3–0–0-0

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1	Immunotechnology	PE-AS-IMT5012	PEC	3	3–0–0-0
1	Medical Information Systems and P CS	PE-AS-MIP513	PEC	3	3–0–0-0
1	Machine Learning for Medical Systems	PE-AS-MLM514	PEC	3	3–0–0-0
1	Computer Aided Drug Designing	PE-AS-CAD515	PEC	3	3–0–0-0
1	Clinical Biochemistry	PE-AS-CBC516	PEC	3	3–0–0-0
1	Infectious Disease Modeling	PE-AS-IDB517	PEC	3	3–0–0-0
1	Material Informatics	PE-AS-MIN518	PEC	3	3–0–0-0
1	Instrumentations	PE-AS-INS519	PEC	3	3–0–0-0
2	Biomedical Engineering for Space	PE-AS-BES520	PEC	3	3–0–0-0
2	Fluid Mechanics for Biological Systems	PE-AS-FMB521	PEC	3	3–0–0-0
2	Survival Analysis	PE-AS-SAN522	PEC	3	3–0–0-0
2	All the electives provided in M. Tech BI basket are available for M. Tech BME students also				
2	**OPEN ELECTIVES**				
2	Open Elective from IT		OE	3	
2	Open Elective from ECE		OE	3	

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Syllabus for M. Tech BME

Biomedical Circuits and Instrumentation

1. Name of the Course and Code: Biomedical Circuits and Instrumentation (PC-AS-BCI501)

2. LTP structure of the course: 3-0-1

3. **Objective of the course:** To instruct about medical instruments currently in use in medical domain with a special focus on the building blocks of such instruments.

4. **Outcome of the course:** Familiarity with key Medical Devices such as ECG, EMG, EEG, Cardiac Output Computer, Blood Pressure Measurement, Plethysmograph, Ultrasound Machine, etc., their operation principle, static and dynamic characteristics.

5. Course Plan:

Component	Unit	Topics for Coverage
Component 1	Unit 1	Transducers for Biomedical Application: Resistive transducers – Muscle force and Stress (Strain gauge), Spirometers (Potentiometric), humidity, Respiration (Thermistor); Inductive Transducers – Flow measurements, muscle movement (LVDT).
	Unit 2	Capacitive Transducers – Heart sound measurement, Pulse pick up; Photoelectric Transducers - Pulse transducers, Blood pressure, oxygen Analyses; Piezoelectric Transducers – Pulse pickup, ultrasonic blood flowmeter; Chemical Transducer:
Component 2	Unit 3	ECG (Amplifiers and Circuits), EEG, Plethysmography, Cardiac Output Measurement.
	Unit 4	Ultrasonic Transducers and Ultrasonic Imaging, Beam Steering, Flowmeters, Full Body Plethysmograph, EMG

6. Text Books:

i. D. Patranabis, Sensors and Transducers, Prentice Hall of India, 2nd Edition,1984

ii. H. S. Kalsi , Electronics instrumentation, Tata Mc Grow Hill education Pvt. Ltd., 3rd edition 2010.

iii. Jon. B. Olansen and Eric Rosow, Virtual Bio-Instrumentation Biomedical, Clinical and Healthcare Applications using LabVIEW, Prentice Hall, first edition, 2002.

Biomechanics

1. Name of the Course and Code: Biomechanics (PC-AS-BOM503)

2. LTP structure of the course: 3 - 0 - 1

3. Objective of the course: This course will focus primarily on the various aspects of application of the principles of mechanics to the study of biological systems - covering the interaction of the human body with the physical world by combining principles from biology and physics - statics, dynamics, muscle activation, mechanical properties of muscle and movement analysis.

4. Outcome of the course: The students will learn the concepts of mechanics concerning to human movement, particularly those pertaining to exercise, sport, and physical activity. The student should gain an understanding of the mechanical and anatomical principles that govern human motion and develop the ability to link the structure of the human body with its function from a mechanical perspective. They will understand the domain of Biofluidmechanics and Cardiovascular mechanics, which will help them in understanding the governing laws of physics related to the mechanical behavior, as well as movement of fluid present in our body. Furthermore, in this course it is desired that each student be able to: 1) describe motion with precise, well-defined mechanical and anatomical terminology; 2) understand and quantify linear and angular characteristics of motion; 3) understand the quantitative relationships between angular and linear motion characteristics of a rotating body; and 4) understand and quantify the cause and effect relationship between force and linear and angular motion.

5. Course Plan:

Component	Unit	Topics for Coverage

Component 1	**Unit 1:**	Introduction to biomechanics, Joint mechanics, Human joint forces, Mechanics of elbow joints, Mechanics of shoulder joints, Mechanics of hip joints, Mechanics of knee joints, Mechanics of ankle joints
	Unit 2:	Tissue mechanics, Introduction, Mechanical properties, Biological materials, Bone as composite material, Adaptation of bone stress and strain, Properties of cortical bone., Properties of cancellous bone, Teeth and its properties, Viscoelasicity, Dynamic behavior, Viscoelastic model, Soft tissue mechanics, Soft tissue properties: contribution of collagen, Elastin and mucopolysaccarides, Mechanical testing of soft tissue
	Unit 3:	Human locomotion, Gait analysis, Events of gait, Variable measured during gait, Motion analysis, Energy considerations, Muscles function, Force data, Prediction of segment moment of inertia, Measurement devices, Kinematics, Foot pressure pedobarograph.
Component 2	**Unit 4:**	Biofluid mechanics, Introduction, Viscosity and viscometry, Capillary viscometer, Coaxial cylindrical viscometer, Cone and plate viscometer, Blood, Model of peripheral circulation, Coagulation, Blood rheology and its clinical application, Red cell size and shape, Cell membrane, Osmotic swelling, Area dilation, Shear of membrane, Synovial fluid
	Unit 5:	Cardiovascular mechanics, Layers of heart wall, Chambers of heart, Heart valves, Blood supply to myocardium, Conduction system, Heart sound, Heart rate cardiac cycle, Electrical activity of heart, Cardiac output, Disease of cardiovascular system, Artificial heart valve, Design of valve, Structural deterioration of biological valves

6. Suggested Text & References:

(i) Fung, Y. C.: Biomechanics: Mechanical Properties of Living Tissues. 2nd Ed., Springer

(ii) C. Ross Ethier and Craig A. Simmons: Introductory Biomechanics: From Cells to Organisms. Cambridge University Press.

(iii) J.D. Humphrey and S.L. Delange. An Introduction to Biomechanics: Solids and Fluids, Analysis and Design. Springer.

(iv) B. Alberts, D. Bray, J. Levis, M. Raff, K. Roberts & J. D. Watson: Molecular Biology of the Cell; 5th Ed, Garland Science.

(v) R. Kamm and M. K. Mofrad. Cytoskeletal Mechanics: Models and Measurements. Cambridge University Press.

(vi) Supplementary Class notes

Biosignal Processing

1. Name of the Course and Code: Biosignal Processing (ES-AS-BOP504)

2. LTP structure of the course: 3-0-1

3. **Objective of the course:** To impart understanding of Signals and their transformation.

4. **Outcome of the course:** The students are expected to be concurrent with understanding Biological Signals acquisition, sampling rate and its impact, discrete domain analysis and application of signal processing tools to extract information relevant to the medical domain.

5. Course Plan:

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	Essentials of continuous time signals and systems: convolution,; Discrete time signals and systems.
	Unit 2	Sampling and quantization, the sampling theorem and signal reconstruction; Z-transform, Filters
Component 2	Unit 3	Fourier transforms, system transfer functions, Frequency analysis of discrete signals and systems: the discrete Fourier transform,
	Unit 4	Power spectrum estimation and system identification; Systems with Feedback Control: stability analysis.

6. Text Books:

i. A.V. Oppenheim, A.S. Willsky& H.S. Nawab: Signals & Systems, Prentice Hall, India, 1997 Discrete Time Signal Processing, Oppenheim, Schaefer, Pearson

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Biomath and Biostatistics

1. Name of the Course: Biomath and Biostatistics (BS-AS-BMB505)

2. LTP structure of the course: 3-0-1

3. **Objective of the course:** To expose students to numerical methods of relevance to computational Biology and Bioinformatics

4. **Outcome of the course:** Students will be able to convert a qualitative problem into computer based solutions

5. Course Plan:

Component	Unit	Topics for Coverage
Component 1	Unit 1	Introduction, Taylor series; Least square method; Curve fitting; Solving ordinary differential equations; Partial differential equations; Matrix algebra; Eigen Values and Eigen Vectors; Optimization and minimization
	Unit 2	
Component 2	Unit 3	Events and Probability Spaces; Conditional Probability; Independence; Random Variables and Distributions; Expectation; Special Distributions: Binomial, Poisson and Normal distributions, Central Limit Theorem and it's applications, Estimation.
	Unit 4	

6. **Text book:** Numerical Methods for Engineers by Chapra and Canal

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Molecular Biology

1. Name of the Course and code: Molecular Biology (ES-AS-MBO506)

2. **LTP structure of the course:** 3-0-1

3. **Objective of the course:** The aim of this course is to providethefundamental knowledgeon cellular and molecular biology for students coming from engineering background.They will be able to understand cellular function, biomolecules, cell division control etc.

4. **Outcome of the course:** At the end of the course the student will be able to outline the molecular and cellular mechanisms involved in the development and growth in cellular level.

5. Course Plan:

Component	**Unit**	**Topics for Coverage**
Component 1	1	Structure and Functions of Nucleic Acids, Chemical structure of DNA and RNA, Watson-Crick model, Supercoiled DNA,
	2	DNA replication, repair and recombination, PCR , Gel Electrophoresis,
Component 2	3	Structure and function of RNA polymerases. Transcription factors and machinery in Prokaryotes, formation of initiation complex, transcription activators and repressors, RNA polymerases, capping, elongation and termination, RNA processing, RNA editing, splicing, polyadenylation,,
	4	Protein synthesis and processing Ribosome, formation of initiation complex, initiation factors and their regulation, elongation and elongation factors, termination, genetic code, SDS PAGE,

6. Text Book and References

i. Freifelder D (2012). Molecular Biology, 5th edition. Narosa Publishing House, India

ii. Berg JM, Tymoczko JL, Gatto GJ and Stryer L (2015) Biochemistry, 8th Edition, WH Freeman & Co., New York. iii. Allison A. Lizabeth (2012) Fundamental Molecular Biology, 2nd Edition. J Willey and Sons, Hoboken,New Jersey.

iv. Freifelder D and Malacinski GM (2005) Essentials of Molecular Biology, 4th Edition, John and Bartlett Publishing, UK

v. Watson JD, Baker TA, Bell SP, Gann A, Levine M and Losick R (2008) MolecularBiology of the Gene, 6th edition, Cold Spring Harbour Laboratory Press, PearsonPublication.

Anatomy & Physiology

1. **Name of the Course and Code: Anatomy & Physiology** (**ES-AS-APH507**)

2. LTP structure of the course: 3-0-1

3. **Objective of the course:** The aim of this course is to teach about human anatomy which is the study of the structures associated with the human body and physiology which is the study of the function of each of these structures.

4. **Outcome of the course:** Knowledge of human anatomy and physiology is very essential for biomedical students. Students will learn about anatomy, basic human physiology and the normal functioning of all the organ systems of the body and their interactions. They will accumulate ideas of physiological aspects of normal growth and development. Students also learn about how organ systems are interconnected in biological systems.

5. Course Plan:

Component	**Unit**	**Topics for Coverage**

Component 1	Unit 1	Bones of appendicular skeleton – Scapula, humerus, radius, ulna, Joint - Hip, Femur, ankle and foot,
	Unit 2	Principal Muscles – Deltoid, Biceps, triceps, respiratory, abdominal and gluteal
Component 2	Unit 3	Basic cell physiology; Biochemical cycles. Systemic physiology: Nervous System, Neuromuscular system; Blood and lymph; Circulatory system; Respiratory and Cardiovascular system.
	Unit 4	Gastro-intestinal system; Kidney and excretory system. Sensory systems- visual, auditory, vestibular; Endocrine- pituitary, adrenal, pancreas, Clinical and technological implications.

6. Text Books:

i. Arthur C. Guyton : Textbook of Medical Physiology, 8th ed, Prism Books (Pvt) Ltd & W.B. Saunders Company, 1991.

ii. W.F.Ganong, Review of Medical Physiology, 13th ed., Prentice-Hall, 17th edition, 1995.

Advanced Medical Instrumentation

1. Name of the Course and Code: Advanced Medical Instrumentation (PC-AS-AMI508)

2. LTP structure of the course: 3-0-1;

3. Prerequisite for the course: NIL

4. Objective of the course:

To introduce students to principles, applications and working of medical instruments most commonly used in medical instrumentation systems used for diagnostic medical applications.

Prerequisite: Physics, Biopotential Measurement and techniques, Human Anatomy and Physiology.

5. Outcome of the course:

Component	Unit	Topics for Coverage
Component 1	**Unit 1**	Concept of microcontrollers, microprocessors, devises safety, ethics and regulatory standards in medical instruments, EMI testing,
	Unit 2	Molecular/ MEMS Sensors and Micro/Nanodevices for Biomedical Engineering Applications,
Component 2	**Unit 3**	Biomedical Instrument Design, Applications of Biomedical Instrumentation Lab, Software Design and Implementation, Introduction to Embedded Systems, Fundamentals of Electronic Circuits,
	Unit 4	Embedded Systems Design Laboratory, Embedded and Real-Time Systems Laboratory, Real-Time Digital Signal Processing Laboratory, Digital Signal Processing

7. Suggested Text & References:

i. R. S. Khandpur "Handbook of Bio-Medical Instrumentation", Tata McGraw Hill.
ii. Carr& Brown, "Introduction to Biomedical Equipment Technology" Pearson Education, Asia.
iii. J.Webster, "Bioinstrumentation", Wiley & Sons.
iv. R S Khandpur, Handbook of Analytical Instruments, Second Edition
v. Joseph Bronzino, " Biomedical Engineering and Instrumentation", PWS Engg . , Boston.
vi. Geddes &Baker , "Principles of Applied Biomedical Instrumentation" Wiley.
vii. Leslie Cromwell, " Biomedical Instrumentation and Measurements"

Biomedical Imaging

1. Name of the Course and Code: Biomedical Imaging (PC-AS-BIM509)

2. LTP structure of the course: 3-0-1

3. **Objective of the course:** The aim of the course is to teach physics of various medical imaging techniques. We will study how sound wave propagates in tissue medium and interacts with the same; how sound beams for imaging can be generated. How can blood velocity be measured using Doppler's shift of ultrasound waves? How the simple principle of interference of light waves can be used to develop an imaging modality will be shown in this course. The generation and detection of X-rays for medical imaging are done in practice will be described. Its interaction with tissue will be outlined. Besides, the concept of tomography imaging and reconstruction using the backprojection method will be introduced. The derivation involving solution of linear equations to obtain image matrix will be carried out. The physics of nuclear structure, its magnetic properties will be illustrated in detail. The interaction of nucleus with external magnetic field will also be highlighted. The effects of application and withdrawal of external magnetic field on an ensemble of nuclei leading to magnetic resonance signals will be presented. Finally, methods to localize magnetic signals coming from a macroscopic system (e.g. human body) for generating images will be described.

4. **Outcome of the course:** This course will help to understand as well as to develop a strong foundation on underlying physics of medical imaging. This will provide enough background and confidence to conceive methods of modern medical imaging and accordingly to pursue research projects.

5. Course Plan:

Component	**Unit**	**Topics for Coverage**
Component 1	**Unit 1**	**US imaging**- Ultrasound wave propagation in homogenous medium, scattering, absorption and attenuation of ultrasound waves in tissue, pulse-echo imaging, pulse parameters, ultrasound transducers, field calculation for a single element transducer, delay-sum beamforming for array transducers, Doppler ultrasound

		Optical coherence tomography-Michelson Morley experiment
	Unit 2	**X-ray imaging**- Instrumentation, mechanism of attenuation of X-ray in tissue, scintillation detection, digital radiography, X-ray CT, backprojection algorithm
Component 2	**Unit 3**	**MRI imaging**-angular momentum, nuclear magnetic moment, Zeeman effect, Larmour precision, T_1, T_2, T_2* relaxations, chemical shift, free induction decay, 90^0, 180^0 pulse sequence, magnetic coils, localization of MRI signals.
	Unit 4	**Nuclear imaging**-introduction to SPECT, and PET, pair production, coincidence detection

6. Text Books:

I. The Essential Physics of Medical Imaging, Bushberg, Lippincott, Williams and Wilkins, Third Edition.

II. The Physics of Medical Imaging, Webb, CRC Press, 1988.

Medical Sensors and Actuators

1. Name of the Course and Code: Medical Sensors and Actuators (PC-AS-MSA510)

2. LTP structure of the course: 3-0-1;

3. Prerequisite for the course: 1.College math and calculus, and differential equations 2.Basic college-level physics and chemistry**.**

4. Objective of the course:

Key aim is to learn Medical Sensors and Actuatorsand micro-integrated system. In this course, major types of molecular sensor systems will be introduced along with, device miniaturization, and detection mechanisms, including molecular capture mechanisms. Diverse transducers i.e. electrical, optical, and

mechanical will be analyzed. Also, micro-array analysis of biomolecules, semiconductor and metal nanosensors; microfluidic systems, will be discussed. Additionally, microelectromechanical systems (MEMS, BioMEMS) fabrication and applications for biomedical engineering will be briefed.

5. Outcome of the course:

After attending the course students should

(a) have comprehensive knowledge of the operation of micro- and nano-scale medical devices, their applications and the technologies used to fabricate them, and

(b) be able to analyze& design a range of medical sensing and actuating devices using relevant mechanical/electrical engineering principles.

(c) be able to work in a fabrication lab and build simple sensing and actuating systems.

6. Course Plan:

Component	**Unit**	**Topics for Coverage**
Component 1	**Unit 1**	Introduction to major types of molecular sensor systems, device miniaturization, and detection mechanisms, including molecular capture mechanisms. Glucose sensor.
	Unit 2	Electrical, optical, and mechanical transducers.QCM, SPR based sensor
Component 2	**Unit 3**	Micro-array analysis of biomolecules; Nano sensors design, advantages
	Unit 4	Microfluidic systems; and microelectromechanical systems (MEMS, BioMEMS) fabrication and applications for biomedical engineering.

LIST OF ELECTIVES

1. Bioelectrics

1. Name of the Course and Code: Bioelectrics (PE-AS-BIE501)

2. LTP structure of the course: 3-0-0

3. Objective of the course: To introduce students to the effect of electrical energy and its interaction with biological tissue.

4. Outcome of the course: Familiarity with concepts such as electroporation, cell and membrane dynamics under electrical stress, impact of electroporation on ion movement, electrical shock and electrical exposure to tissue and its effect. Students should also become familiar with excitation models and the notion of strength-duration characteristics, tissue impedance in micro and macro scales.

5. Course Plan:

Component	Unit	Topics for Coverage
C 1	Unit 1	Introduction (General Idea/Electrical Exposure/Short-term exposure/ reactions Threshold and Variability, Bio-impedance and Current, Dielectric Properties (Cellular membrane/ Skin Impedance - LF and HF), High Voltage and Transient Properties, Full body impedance,
	Unit 2	Ion channels, Gibbs Donnan Equilibrium, RMP , Action Potential, HH model Cardiac Action Potential (Dynamics and Recovery)
C 2	Unit 3	Electroporation (Introduction/ Electroporation density
	Unit 4	E-field /Electroporation and Membrane conductivity)

6. Text Books:

I. Applied Bioelectricity: J. Patrick Reilly, Springer Publications, ISBN 0-387-98407-0

II. Bio electricity: A Quantitative Approach [Hardcover] - Robert Plonsey, Roger C. Barr, Springer, 3rd edition (June 21, 2007)

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2. Biomaterials and Tissue Engineering

1. Name of the Course: Biomaterials and Tissue Engineering (PE-AS-BTE502)

2. LTP structure of the course: 3-0-0

3. Objective of the course: The aim of the course is to teach the development of biomaterials and its response with the host body which is an emerging aspect of medical device development.

4. Outcome of the course: Understand the fundamental principles in biomedical engineering, material science and chemistry, and how they contribute to development biomaterial and its performance. Students will gain knowledge about how to do biomaterial selection and design. It will be useful in the understanding of properties of synthetic and natural biomaterials, new and different classes of materials used in biomedical applications, and the various factors (materials properties, biologic response, etc.) that define the utility and applications of these materials.

5. Course Plan:

Component	**Unit**	**Topics for Coverage**
Component 1	**Unit 1**	Introduction to Materials in Medicine, Classification of materials. Fundamentals of biomaterials science. Evolution of biomaterials. Physico-chemical properties of biomaterials: mechanical (elasticity, yield stress, ductility, toughness, strength, fatigue, hardness, wear resistance).

	Unit 2:	Natural polymers in synthesis of biomaterials, Degradable polymers,Surface treatments and analysis. Case study of few advanced biomaterials.
Component 2	**Unit 3:**	Phenomena at the biointerfaces. Interactions between biomaterials and tissues. Surface interactions. Cell-Biomaterial Interactions and Host Integration. Concept of biocompatibility.
	Unit 4:	Cells, Tissue organization. Structure, morphology and properties. Cell-matrix interactions. Stem cell engineering. Use of biomaterials in Stem cell engineering.

6. Text Book:

I. Lanza RP, Langer R, Vacanti JP, Principles of Tissue Engineering, Academic Press, 3rd Edition (2007).

II. Palsson B and Bhatia SN, Tissue Engineering, Pearson Prentice Hall (2003).

III. Biomaterials Science: An Introduction to Materials in Medicine - *Buddy D. Ratner, Allan S. Hoffman, Frederick J. Schoen, Jack E. Lemons, second sedition.*

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3. Medical Image Processing

1. Name of the Course and Code: Medical Image Processing (PE-AS-MIP503)

2. LTP structure of the course: 3-0-0

3. Objective of the course: The goal of the course will be to introduce methods of image processing and the application of mathematical approaches for quantifying image parameters.

4. Outcome of the course: The students will become familiar with the mathematical concepts of image processing tools. They will learn how various image parameters can be quantified using signal processing schemes. The physics and instrumentation aspects of advance biological image recording techniques will be demonstrated. They will also become conversant with the computational tools for extracting image parameters.

5. Course Plan:

Component	Unit	Topics for Coverage
C 1	Unit 1	Basics of the Fourier series, transform, DFT, FFT, filter designing in frequency domain, image smoothing using frequency domain filters, image sharpening using frequency domain filters
	Unit 2	Introduction to wavelet analysis, multiresolution expansion, WT in 1D, WT in 2D, Types of wavelets-Haar wavelet, Daubechies wavelet, Biorthogonal wavelet. Coislet wavelet, Morlet wavelet, Mexican Hat wavelet, Symlet wavelet. Medical applications.
C2	Unit 3	Optical microscopy, scanning electron microscopy, transmission electron microscopy, atomic force microscopy
	Unit 4	Application of image processing tools on microscopic imaging

6. Text books:

I. Digital Image Processing, Gonzalez and Woods, Pearson, Third edition.

II. Fundamentals of light microscopy and electronic imaging, Murphy and Davidson, Wiley, Second edition.

4. Nanobiotechnology and Informatics

1. Name of the Course and Code: Nanobiotechnology and Nanoinformatics (PE-AS-NBN504)

2. LTP structure of the course: 3-0-0

3. Objective of the course: The aim of this course is to provide the fundamental knowledge on nanotechnology, engineering at nanoscale for development of advanced materials suitable for various biomedical applications. Learning of how to monitoring the properties of the materials depending on the size and shape. Study the interaction of the nanosize materials with biomacromolecules using computational approaches as well.

4. Outcome of the course: Students are going to learn about the various synthesis method of nanoscale materials, how these nanoscale materials interacts with biological cells and influences intra cellular events. Usefulness of such advanced materials for development of sensitive biosensors and novel therapeutics.

5. Course Plan:

Component	Unit	Topics for Coverage
Component 1	1	Introduction to Nanotechnology, Classification of Nanoscale materials. Concept of Nanobiotechnology and bionanotechology. One dimensional, Two dimensional and Three dimensional nanostructured materials, Quantum Dots shell structures, metal oxides, semiconductors, composites. Influence of nano over micro/macro, size effects and crystals.
	2	Surface to volume ratios of nanoscale materials, Role of Dangling bonds. Unique optical (SPR, Fluorescence), catalytic, chemical properties of nanoscale materials. Characterization of NPs by X-ray diffraction, powder diffraction, lattice parameters, Transmission Electron Microscopy (TEM) and Scanning Electron Microscope (SEM)

Component 2	3	Various synthesis methods of nanoscale materials, Top down and Bottom up approach, Lithography, Chemical reduction.
	4	Design of Nano-sensors. Nano-sensors for detection of biomolecule. Antibacterial and Anti-cancer activity of NPs, Drug targeting, drug delivery, DNA-Nanoparticle interactions, Protein- NPs interactions, Binding Energy.

6. Text Book and References

- A Textbook of Nanoscience and Nanotechnology by Prof. T. Pradeep
- Nanotechnology Applied To Pharmaceutical Technology, Editors Prof. Mahendra Rai and Dr. Carolina Alves dos Santos, 2017

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5. Bio-Medical Micro-Electro-Mechanical Systems (Bio-MEMS)

1. Name of the Course and Code: Biomedical Micro-Electro-Mechanical Systems **(PE-AS-BIM505)**

2. LTP structure of the course: 3-0-0

3. Prerequisite for the course: 1.College math and calculus, and differential equations 2.Basic college-level physics and chemistry**.**

4. Objective of the course:

Key aim is to learn micro-electro-mechanical systems (MEMS) and micro-integrated system. Properties of useful materials will be discussed in context to MEMS and BioMEMS. Micro-electronics process modules used in the design and fabrication of MEMS and micro-integrated systems will be presented. Applications of these systems in a variety of sensors and transducers for broad ranges of implantable biomedical applications will be described. Recent advances in wearable biomedical applications of MEMS and bioMEMS will also be discussed in detail.

5. Outcome of the course:

After attending the course students should:-

(a) have detailed knowledge of the operation of micro- and nano-scale devices, their applications and the technologies used to fabricate them, and

(b) be able to analyze& design a range of devices using relevant mechanical/electrical engineering principles.

(c) be able to work in a fabrication lab and build simple systems.

6.Course Plan:

Component	**Unit**	**Topics for Coverage**
C 1	**Unit 1:**	(1) Introduction: micro- and nano-scale size domains; scaling of physical laws; MEMS materials and processes; MEMS devices and applications
	Unit 2:	(2) Introduction to Submicron Technology: semiconductor materials; photolithography; doping; thin film growth and deposition; CVD and Ion Implantation, metallization; wet and dry etching; silicon micromachining; metal MEMS processes; submicron optical lithography; electron beam lithography; soft lithography and printing; bonding and sacrificial processes; polymer processing and rapid prototyping; biomaterials and biocompatibility issues.
C 2	**Unit 3:**	(3) micro total analysis system (μTAS): Fluid control components, μ-TAS: sample handling, μ-TAS: separation components, μ-TAS: detection, cell handling and characterization systems, systems for biotechnology and PCR,polynucleotide arrays and genetic screening, miniatuare biosensors, biosensors arrays.

	Unit 4:	(4) implantable devices, neural interfaces, microsurgical tools, microneedles, and drug delivery, miniature bireactors and Microsystems for tissue engineering, tissue scaffolds, optical biosensors, MEMS metrology, MEMS packaging.

7. Suggested Text & References:

i. Course notes – will be posted weekly on the course website

ii. Foundations of MEMS, Chang Liu, Prentice Hall (2006)

iii. Fundamentals of Micro fabrication, Marc Madou, CRC (2002)

iv. Introduction to BioMEMS – Albert Folch, CRC (2012)

v. Manz and H. Becker, Eds. Microsystem Technology in Chemistry and Life Sciences Spronger-Verlag, New York, 1999. ISBN: 3-540-65555-7.

vi. Chang Liu, Foundations of MEMS, 2nd Edition, Pearson/Prentice Hall, 2011. (Introductory-Intermediate)

vii. Stretchable Electronics, Takao Someya, WILEY-VCH. ISBN: 978-3-527-32978-6 (2013). (This book is available to download free in Purdue library. Handouts will be distributed when lecture topics are not included in the book.)

viii. Gregory T.A. Kovacs, Micromachined Transducers Sourcebook, McGraw Hill, 1998

ix. Stephen D. Senturia, Microsystem Design, Kluwer Academic Publishers, 2000

x. S. M. Sze, ed., Semiconductor Sensors.New York: John Wiley, 1994.

xi. R. S. Muller, et.al.,Microsensors.New York: IEEE Press, 1991.

xii. M. Madou, Fundamental of Microfabrication, CRC Press, Inc. Boca Raton, FL., 1997

xiii. M. Elwensoek, H. Jansen, "Silicon Micromachining," Kluwer Academic Publishers, 1998

xiv. J.W. Gardner, “Microsensors –Principles and Applications,” John Wiley &Sons, 1994

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6. Artificial Organs and Implants

1. Name of the Course and Code: Artificial Organs, and Implant **(PE-AS-AOI506)**

2. LTP structure of the course: 3-0-0

3.Prerequisite for the course: Human Anatomy & Physiology, Fundamentals of Mechanics, Electronics and Electrical Engineering.

4. Objective of the course:

i. To know about various types of assist devices.
ii. To give a basic idea of the artificial organs that can aid a human to live a normal life. 3.To provide the awareness of how a help can be rendered to a differently abled person

5. Outcome of the course:

i. Have knowledge about various types of assist devices.
ii. Students will have the ability to choose which type of assist device is suitable for various disorders and legal aspects related to rehabilitation.
iii. Students will have the urge to develop new devices based on the basic knowledge gained in different assisting devices.

6.Course Plan:

Component	**Unit**	**Topics for Coverage**
C 1	**Unit 1:**	• Introduction to artificial organs: Biomaterials used in artificial organs and prostheses. inflammation. rejection. correction, problems associated with extracorporeal blood flow. • Introduction (definitions, requirements, strategies, type of replacements, historical review), Review of major physiological systems, Basic concepts in mechanics of materials, Structure of biological tissues, Human joints (shoulder, elbow, wrist, hip, knee, ankle), Total replacement of the knee and hip joints, Osseointegrated implants and bone replacements, Upper and lower limb prostheses, Respiratory assist devices, Neural implants, Eye prosthetic devices, Urologic prosthetic devices, Cosmetic implants, Artificial Skin, Artificial Blood.

	Unit 2:	• Artificial kidney: Brief of kidney filtration, basic methods of artificial waste removal. hemodialysis. equation for artificial kidney and middle molecule hypothesis. Hemodialysers: flat plate type, coil type and hollow fiber. Analysis of mass transfer in dialyers (cross current &cocurrent flow). regeneration of dialysate. membrane configuration, wearable artificial kidney machine. separation of antigens from blood in ESRD patients.
C 2	**Unit 3:**	• Artificial heart-lung machine: Brief of lungs gaseous exchange transport. artificial heart-lung devices. Oxygenators: bubble. film oxygenators and membrane oxygenators. Gas flow rate and area for membrane oxygenators. • Heart assist devices: principles, functionality, types of ventricular assist devices (VAD) and total artificial hearts (TAH), main world known products and manufactures. • Liver support system. artificial pancreas. blood and skin. • Audiometry: air conduction. bone conduction. masking. functional diagram of an audiometer. Hearing aids: different types, receiver amplifiers. • Opthalmoscope, retinoscope, I.A.B.P principle and application.
	Unit 4:	• Rehabilitation Engineering: Impairments. disabilities and handicaps. Measurement and assessment. Characterizing engineering concepts in sensory and motor rehabilitation. Engineering concept in communication disorders. Rehabs for locomotion. visual. speech& hearing. Artificial limb and hands. prosthetic heart valves. Externally powered and controlled orthotics and prosthetics. Myoelectric hand and ann prostheses. The marcus intelligent hand prostheses. gait study, spinal rehabilitation. • Biocompatibility and biomaterials, Chosen aspects of tissue engineering, Regenerative medicine.

		• Future of artificial organ, Ethical, economical, environmental and legal aspects in artificial organs domain.

7. Suggested Text & References:

1) Hand book of biomedical engineering. Bronzino. Joseph
2) Hand book of biomedical instrumentation. R. S. Khandpur
3) Artificial Organs. Erie. D. Blom Howard. B. Rotham.
4) Biomedical Engineering Principles (Volume — II). David 0. Cooney., Marcel Dekker Inc.
5) Robbinson C.J., Rehabilitation Engineering. CRC press 1995
6) Ballabio E. etal, Rehabilitation Engineering. 105 press 1993.

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7. Engineering Processes in Biological Systems

1. Name of the Course and Code: Engineering Processes in Biological Systems **(PE-AS-EPB507)**

2. LTP structure of the course: 3-0-0

3. Prerequisite for the course: Human anatomy and physiology, Control system& analysis, Physics, Higher Engineering Mathematics.

4. Objective of the course:

The purpose of this course is to acquaint each student with the knowledge of modelling a physiological system and enable them to and thereby enable them to understand its interactions with various other system, and dependency on various conditions affecting its stability &behaviour.

5. Outcome of the course:

After learning the course the students should be able to do:

i. Build on a basic understanding of physiology (from pre-requisites) to develop a more indepthlevel of understanding that will enable engineering analysis of selected physiological systems.
ii. Be able to translate the understanding of physiological function into an engineering model based on block-diagram analysis of a dynamic system whose function is based on a differential equation.
iii. Develop skill in applying a high-level engineering tool for block diagram modeling (SIMULINK).
iv. Be able to apply engineering models of physiological systems to answer questions relevant to the design of biomedical engineering devices or processes.
v. Be able to apply basic principles of steady-state and dynamic negative feedback control to physiological systems.
vi. Be able to recognize the difference between the roles of variables and parameters in a model.
vii. Be able to breakdown a complex physiological system into the function of its component subsystems, and then build an engineering model based on subsystems.

6. Course Plan:

Component	Unit	Topics for Coverage
Component 1	Unit 1	Electrical Processes: Ionic pumps and their activation/deactivation; Cellular membrane & Lipid bi-layer; Ionic regulation; Central Nervous system – Cable model for Nerves (HH Model), Nerve conduction (mechanism and velocity); Cardiac sub-system – Cardiac contraction/expansion cycle, Cardiac potential vectors, ECG, Einthoven's Triangle, Natural Pacemaker. Mechanical Processes: Cellular biomechanics – Viscoelastic model of the cell, Actin filaments (mathematical model), Mechanoreceptors and Cellular response to mechanical stress
	Unit 2	
Component 2	Unit 3	Muscles and Movement – Whole muscle mechanics (Parallel/Pinnate),

	Unit 4	Muscle & Bone Interaction, Gait Analysis; Ocular and Respiratory biomechanics. Transport Processes: Heat Transfer and thermal regulation – Conduction, Biological heat production, Non-biological heat; Mass transfer – Membrane diffusion, Convection, Enzymatic Reactions, Storage; Vascular sub-system – Blood flow, Vascular pressure, Bifurcation.

7. Text Books:

- Introductory Biomechanics: From Cells to Organisms (Cambridge Texts in Biomedical Engineering) - C. Ross Ethier, Craig A. Simmons, Cambridge University Press; 1 edition (March 12, 2007).
- Biological Process Engineering: An Analogical Approach to Fluid Flow, Heat Transfer, and Mass Transfer Applied to Biological Systems - Arthur T. Johnson, Wiley-Interscience; 1edition(December 14, 1998).
- Applied Bio-electricity: From Electrical Stimulation to Electropathology - J. Patrick Reilly, H. Antoni (Contributor), M.A. Chilbert (Contributor), J.D. Sweeney (Contributor), Springer; 1998 edition (August 21, 1998).
- Bio electricity: A Quantitative Approach [Hardcover] - Robert Plonsey, Roger C. Barr, Springer, 3rd edition (June 21, 2007)

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8. <u>Soft Computing Tools for Biomedical Engineering</u>

1. Name of the Course and Code: Soft Computing Tools for Biomedical Engineering (PE-AS-SCT508).

2. LTP structure of the course: 3-0-0

3. Prerequisite for the course: A basic knowledge of physics, calculus and computer programming is required.

4. Objective of the course:

- Understand the different soft computing techniques.
- Understand neural network architectures and learning algorithms, for different applications
- Explore the use of Fuzzy and Genetic Algorithm
- Understand different Optimization techniques in soft computing
- To introduce Hybrid and Other advanced model in soft computing.

5. Outcome of the course:

Upon successful completion of the course student should be able to

- Describe various neural, fuzzy and Genetic algorithms.
- Implement Neural, Genetic and Fuzzy algorithms for various classification applications

6. Course Plan:

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	FROM BIOLOGY TO ARTIFICIAL NEURAL NETWORKS – INTRODUCTION Biological Neural Networks, Components of Artificial Neural Networks – Connections, Propagationfunction and Network Inputs, Common Activation Functions, Threshold, Network Topologies,Learning - Supervised, Unsupervised, Reinforcement. Backpropagation, Radial Basis Function,Self-Organizing Maps, Counter Propagation Networks, Adaptive Resonant Theory (ART).
	Unit 2	FUZZY SET THEORY Introduction to Fuzzy – Fuzzy Sets – Basic Definition and Terminology – Set-theoretic Operations– Member Function Formulation and Parameterization – Fuzzy Rules and Fuzzy Reasoning –Extension Principle and Fuzzy Relations – Fuzzy If-Then Rules – Fuzzy Reasoning – FuzzyInference Systems – Mamdani Fuzzy Models – Sugeno Fuzzy Models

		– Tsukamoto Fuzzy Models – Input Space Partitioning and Fuzzy Modelling.
Component 2	Unit 3	GENETIC ALGORITHM Genetic Algorithms: Introduction to Genetic Algorithms (GA), Representation, Operators in GA,Fitness function, population, building block hypothesis and schema theorem.; Genetic algorithmsoperators methods of selection, crossover and mutation, simple GA (SGA), other types of GA,generation gap, steady state GA.
	Unit 4	OPTIMIZATION USING SOFT COMPUTING Single variable optimization - Region Elimination Methods, Fibonacci Search Method, Multivariable Optimization - Cauchy's Steepest Descent Method, Newton's method, Swarm Intelligence-ParticleSwarm Optimization, ANT Intelligence – ANT Colony Optimization, Artificial Bee Colony Algorithm, Jumping Frog Optimization.
	Unit 5	HYBRID AND ADVANCED MODEL IN SOFT COMPUTING Genetic Algorithm based Back propagation Network, Fuzzy Logic Controlled Genetic Algorithms, Neuro-fuzzy hybrid systems, Support Vector Machine, Extreme Learning Machine (ELM), Extended ELM, Random Forest Algorithm.

7. Text books:

1. J.S.R.Jang, C.T.Sun and E.Mizutani, "Neuro-Fuzzy and Soft Computing", PHI, 2004, Pearson Education 2004.

2. James A Freeman and David M.Skapra, "Neural Networks: Algorithms, Applications, and Programming Techniques", Addison-Wesley, 1991, Digital Version 2007.

3. Davis E.Goldberg, "Genetic Algorithms: Search, Optimization and MachineLearning", Addison Wesley, N.Y., 1989

8. References:

1. LaureneFausett, "Fundamentals of neural networks- Architectures, algorithms and applications", Prentice Hall, 1994.

2. Simon O. Haykins,"Neural Networks: A Comprehensive Foundation", 2nd Edition, Pearson 1994.

3. Zimmermann H.J. "Fuzzy set theory and its Applications" Springer international edition, 2011.

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9. Computational Methods for Biomedical Engineers

1. Name of the Course and Code: Computational Methods for Biomedical Engineers. **(PE-AS-CMB509)**

2. LTP structure of the course: 3-0-0

3. Prerequisite for the course:A basic knowledge of physics, calculus and computer programming is required.

4. Objective of the course:

The purpose of this course is to provide engineering students with an understanding of and hands on experiences with computational methods commonly employed in biomedical engineering research. The student should develop:-

- an in- depth understanding of the theory underlying advanced computational methods in BME.
- skills to apply computational theory in practice using software tools

5. Outcome of the course:

After learning the course the students Should Gain from this Course:

- Knowledge of the principles of computational methods widely employed in biomedical engineering
- Ability to apply and/or evaluate the results of computational methods widely employed in biomedical engineering

- Written and oral communication skills necessary for preparation and peer-review of scientific presentations, articles, and proposals

6. Course Plan:

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	Solving linear algebraic equations Interpolation/extrapolation Numerical integration/differentiation of functions Random number generation; root finding Maximization/minimization of functions
	Unit 2	Fourier analysis Fourier applications Statistical description of data I
Component 2	Unit 3	Statistical description of data Modeling of data
	Unit 4	Pattern Recognition Monte Carlo Preproposal on Pattern Recognition Preproposal on Monte Carlo Project Activities

7. Textbooks and Software Required:

Title: Numerical Recipes

Authors: Press, Teukolsky, Vetterling, Flannery

Publication date and edition: 2007, 3rd edition

ISBN number: 978- 0- 521- 88068- 8

Required Textbooks and Other Materials:

Laptop with MATLAB (MathWorks, Natick, MA) or comparable programming environment, and ability to use online resources/tools such as Canvas. Students are expected to bring their laptops with them to each class session. If you do not have access to a laptop and/or a programming language such as MATLAB, please speak with the instructors right away.

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10. Modeling of Biomedical Engineering Systems

1. Name of the Course: Modeling of Biomedical Engineering Systems **(PE-AS-MBE510)**

2. LTP structure of the course: 3-0-0

3. Prerequisite for the course: A basic knowledge of Human anatomy and Physiology, physics, calculus and computer programming is required.

4. Objective of the course:

The purpose of the course is to introduce and apply methods of general interest in modelling and simulations. The course aims at giving a mix between theory and hands on practice in relevant application areas. The focus is to study methods and applications that are of relevance in biomedical engineering within diagnostic and therapeutic applications as well as for physiological processes.

5. Outcome of the course:

At the end of the course, the student will be able to:

Analyze the behavior of a dynamical system; use software tools; design models to understand its performance; evaluate various strategies for its operation.

Apply proper working methods of biomedical system modeling, with the aim of being applied to solve problems in the field of biomedical engineering as well as in general engineering.

6. Course Plan:

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	Mathematical Modeling of Biomedical Systems using Linear Models Description: Generalized system properties. Linear models of biomedical systems. Steady-state analysis. Stability analysis. Computer analysis and simulation.
	Unit 2	Identification of physiological systems. Parameter estimation. ODEs based modeling,
Component 2	Unit 3	Optimization in Biomedical System,Optimization in systems with Autoregulation, negative feedback; SIM,
	Unit 4	Nonlinearities in Biomedical Control Systems: Complex Dynamics Description: Nonlinear versus linear systems. Nonlinear oscillators. Several models of biomedical systems. Tools of modeling and simulation will be applied. Various strategies for its operation will be evaluated

7. Textbooks and Software Required:

Basic:

- Ljung, Lennart. System Identification. The theory for the user. Englewood Cliffs: Prentice Hall, 1999. ISBN0136566952.
- Khoo, Michael C.K. Physiological control systems : analysis, simulation, and estimation [on line].

2nd ed. Hoboken: John Wiley & Sons, 2018[Consultation:27/05/2020]. Available on: https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=5349055. ISBN 9781119058786.

- Solé Vicente, Ricard ; Susanna C. Manrubia. Orden y caosensistemascomplejos. Barcelona: Edicions UPC, 2001. ISBN 8483014912.

Complementary:

- Medical & biological engineering & computing [on line]. Stevenage, Herts: Peter Peregrinus, 1963- [Consultation: 23/07/2014]. Available on: http://www.springerlink.com/content/1741-0444/?sortorder=asc&p_o=234**.**

- IEEE Transactions on Biomedical Engineering [on line]. New York: IEEE, 1964- [Consultation: 08/09/2020]. Available on: http://ieeexplore.ieee.org/servlet/opac?punumber=10.

- Journal of Applied Physiology [on line]. Bethesda, MD: The American Physiological Society, 1948- [Consultation: 23/07/2014]. Available on: http://jap.physiology.org/front.

- Journal Neurophysiology [on line]. Bethesda, MD: American Physiological Society, 1938- [Consultation: 23/07/2014]. Available on: http://jn.physiology.org/front.most-read.

- Medical Engineering & Physics [on line]. New York: Elsevier, 19??- [Consultation: 23/07/2014]. Available on: http://www.sciencedirect.com/science/journal/13504533.

- IEEE Engineering in medicine an biology magazine [on line]. New York: Engineering in Medicine and Biology Society of the Institute o fElectrical and Electronics Engineers ,1982 - [Consultation:23/07/2014]. Available on: http:// ieeexplore. ieee.org/xpl/RecentIssue.jsp?punumber=51

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11. Telemedicine

1. Name of the Course and Code: Telemedicine **(PE-AS-TEM511)**

2. LTP structure of the course: 3-0-0

3. Prerequisite for the course: Basic knowledge of anatomy and physiology, basic knowledge of medical informatics (corresponding to Medical Information Systems)

4. Objective of the course:

Telemedicine is the use of telecommunication and information technologies in order toprovide clinical health care at a distance. It helps eliminate distance barriers and can improveaccess to medical services that would often not be consistently available in distant rural communities. This course will enable to understand the various techniques used for data transferring in health care services. The course content should be taught and implemented with the aim to develop required skills in the students so that they are able to acquire following competency:

- Use various communication techniques in the field of medical instrumentation.

5. Outcome of the course:

The theory should be taught and practical should be carried out in such a manner that students are able to acquire required learning out comes in cognitive, psychomotor and affective domain to demonstrate following course outcomes:

i. Explain the concept of telemedical system.

ii. Apply the basic communication system and its tools in telemedical Instrumentation.

iii. Use hardware and software tools employed for data exchange.

iv. Develop logic for data security.

v. Apply communication in teleradiology.

6. Course Plan:

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	Introduction of Telemedicine. Why use Telemedicine? History ,Terminology, Types of Telemedicine Systems ,Examples of Telemedicine in Clinical Practice ,Values to the Patient, Clinician, and Health Care Organization , Challenges to Successful Implementation ,Internet in Medicine.

	Unit 2	Healthcare Delivery in Low Resource Settings by using Advanced Technologies , Healthcare in high- and low-resource settings. Healthcare distributions in Low resource settings and corresponding problems. Telemedicine for low-resource settings.
Component 2	Unit 3	Block diagram of telemedicine system in low-resource settings. Telehealth, Telecare, Teleradiology, Tele-oncology, etc. Potential and limitations of Telemedicine and Tele-Health in low resource settings . Basic structures of Telemedicine and Tele-Health in low resource settings . Practical Examples of Telemedicine development in low resource settings. Legal and ethical issues in Low resource settings.
	Unit 4	Services provided through telemedicine , Routine and Follow-up examinations, Urgent Care , Clinical Research ., Medical images , Capture , Electronic Medical Records . Technical Aspects of planning, construction, development and deployment of telemedicine technology systems. Standards in Telemedicine

7. Textbooks:

1. Computer networks, Andrew S Tanenbaum, PHI Learning, New Delhi, 2010,

2. Data Communication and Networking,Forouzan PHI Learning, 2012

3. Electronic Communication Dennis, Roddy; John, Coolen Pearson Education, New Delhi, 2011

4. Electronic Communication Systems Kennedy, George; Davis, Bernard McGraw-Hill Education (ISE Editions),2006

5. Handbook of Tele-medicine Ferrer-Roca, Olga; Sosa, M.Ludicissa IOS press,2002

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12. Immunotechnology

1. Name of the Course: Immunotechnology **(PE-AS-IMT512)**

2. LTP structure of the course: 3-0-0

3. Prerequisite for the course: Open to all graduates, with the prior permission of course instructor.

4. Objective of the course:

This course deals with immune systems and their components at the cellular and humoral levels. Furthermore, this course deals with the practical aspects such as the production and engineering of antibodies, the application of antigens, the design of (recombinant) vaccines, strategies for immune intervention, etc.

5. Outcome of the course: The course will help students to understand the fundamentals of immunology, related disorders and different immunoassay techniques for diagnosis.

6. Course Plan:

Component	Unit	Topics for Coverage
C 1	**Unit 1:**	Introduction to immunology: Cells & organs of immune system-lymphoid cells, B and T lymphocytes, null cells. Mononuclear cells-phagocytosis, antimicrobial and cytotoxic activities. Granulocytes-neutrophils, eosinophils and basophils. Mast cells, dendritic cells. Organs of immune system-primary and secondary lymphoid organs.
	Unit 2:	Immunoglobulins: Structure and function-basic and fine structures of immunoglobulins. Isotypes, allotypes and idiotypes Classification of immunoglobulins. Genetic control of antibody response. Generation of antibody diversity. Theories of antibody formation. Clonal selection theory.Antigen-antibody interaction-strength of antigen-antibody interaction, cross reactivity, precipitin reactions. Radioimmunoassays (RIA). Enzyme linked immunosorbent assay (ELISA). Western blotting. immunoelectron microscopy. Complement proteins, complement features, classical and alternative pathways.
C 2	**Unit 3:**	Major histocompatibiltycomplex(MHC): Structure and its significance. Transplantation immunity-immunological basis of graft rejection, xenotransplantation. Clinical manifestation of graft rejection. General and

		specific immuno suppressive therapy. Clinical transplantation. Hypersensitivity-type I, II, III, and IV hypersensitivity.
	Unit 4:	Autoimmunity: Basis of autoimmune disorders, mechanism for the induction of autoimmunity.Treatment of autoimmune diseases. Immune response to infectious diseases. Antigen presentation via Class I and Class II pathways. Th1/ Th2 polarities, NK Effector Mechanism. Apoptosis. Monoclonal antibodies-production role and advantages of monoclonal antibodies. Detailed account on the application and uses of monoclonal antibodies. Humanization of antibodies. Cancer Immunology: Role of cytotoxic T lymphocytes in cancer immunology. AIDS pathogenesis, immunology of retroviruses, role of chemokines in management of AIDS. Vaccine technology, active and passive immunity, development of vaccine against infectious diseases.

7. Suggested Text & References:

1.Thomas J. Kindt, Richard A. Goldsby, Barbara A. Osborne.Immunology,6thed., W. H. Freeman, 2006,ISBN-10:0716767643| ISBN-13: 9781429203944.

2. Abul K. Abbas and Andrew H. Lichtman,Cellular and Molecular Immunology,2014,ISBN-10: 0323222757 ISBN-13: 978-0323222754

3. David K. Male, Jonathan Brostoff, David E. Roth, and Ivan M. Roitt,Immunology,8threvised edition, Elsevier, 2012, ISBN-10: 0323080588 | ISBN-13: 9780323080583

4. Thao Doan, Roger Melvold, Susan Viselli, Carl Waltenbaugh, Immunology, Lippincott Illustrated Reviews Series,2012, ISBN-10: 1451109377| ISBN-13: 978-145110937

13. Medical Information Systems and PACS

1. Name of the Course and Code: Medical Information Systems and PACS (PE-AS-MIP513)

2. LTP structure of the course: 3-0-0

3. Objective of the course:

The student will be able to:

- Identify the major hardware components and their peripherals that are involved with the healthcare IT information systems
- Distinguish between the different software layers and applications
- Obtain a basic knowledge about the different Operating Systems and Database systems

4. Outcome of the course:

After the course the students will be able to:

- Perform basic hardware and software maintenance and upgrades
- Execute basic operating system commands and run utilities
- Perform simple queries using SQL
- Perform basic diagnosis using standard utilities and tools

5. Course Plan:

Component	Unit	Topics or Coverage
C1	Unit 1	Healthcare Data, Information and Knowledge Consumer Health Informatics Online Medical Resources

		Search Engines Evidence Based Medicine and Clinical Practice Guidelines
	Unit 2	Disease Management and Registries Quality Improvement Strategies Electronic Health Records Practice Management Systems Health Information Exchange
C2	Unit 3	Data Standards Privacy and Security Health Information Ethics Mobile Technology Architectures of information Systems
	Unit 4	Patient Safety and Health Information Technology E-prescribing Telehealth and Telemedicine Picture Archiving and Communication Systems E-Research Public Health Informatics

6. Texts & References

Hoyt, R., &Yoshihashi, A. (2012). Health Informatics: Practical Guide for Healthcare and Information Technology Professionals (5th ed.). Lulu Press, Inc.

Additional References:

• IEEE-ACM Software Engineering Code of Ethics and Professional Practice

• The UWF Medical Informatics Resource Site: http://uwf.edu/sahls/medicalinformatics

• Optional Tutorials: Several tutorials will be posted during the course for various activities.

• See additional links embedded in modules in eLearning.

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14. Machine Learning for Medical Systems

1. Name of the Course and Code: Machine Learning for Medical Systems (PE-AS-MLM514)

2. LTP structure of the course: 3-0-0

3. Objective of the course: To give exposure in need of application of customized form of machine learning approach to solve various types of biomedical problems. For example, automated diagnostics through medical signal and image processing, semantic study of biological strings (DNA, RNA and Protein chains) to help faster drug design, problems of classification of protein structure, etc.

4. Outcome of the course: Knowledge gained through this course will generate human resource with skill in dealing with classification and decision problems for complex real life area in general and biomedical are in particular.

5. Course Plan:

Component	Unit	Topics or Coverage
C1	Unit 1	Foundation of Machine learning: Turing Machine, Concepts of John von Neumann, computation of amount of learning of a machine, Concept of

		supervised and unsupervised learning, concept of clusters and classes, concept of training and testing.
	Unit 2	Statistical Machine Learning: Design of rule based expert system, knowledge engineering, forward chaining and backward chaining inference techniques, Application to discriminate intron from exon within eukaryotic DNA, Application of rule based system to discover knowledge from data, concept of clustering, condition to find best clusters. Various clustering techniques, Important components of a classifier, Probabilistic classifier, Bayesian classifier, Nearest Neighbor Classifier, Discriminant Function Analysis (Linear and non-linear) as precursor to Artificial Neural Network.
C2	Unit 3	Hidden Markov Models and applications, Applications to discriminate Exon from Intron, to predict secondary structures of proteins, discover group of genes having similar up-regulation or down-regulation pattern from micro-array data.
	Unit 4	Soft computing method based machine learning: Artificial Neural Network for clustering and classification, local optimization of ANN weights, Back propagation network, Hopfield network, Genetic algorithm for optimizing parameters of classifiers, Support Vector Machine foundation, constrained local optimization using Lagrange, Multiplier, application and Cross validation.

6. Text Books:

- Pattern recognition and image analysis by Earl Gose.
- Pattern Classification by Duda, Richard and David Stork
- Machine Learning by Mitchell and Tom

7. Reference book: Artificial Intelligence and Molecular Biology, Lawrence E. Hunter, MIT Press

15. Computer Aided Drug Designing

1. Name of the Course and Code: Computer Aided Drug Designing (PE-AS-CAD515**)**

2. LTP structure ofthe course: 3-0-0

3. Objective of the course: The course aims to educate students with all the latest developments in drug design based on computational techniques. The field of computer-aided drug design has had extensive impact in the area of drug design.

4. Outcome of the course:

At the end of the course students will be able to:-

- Explain the various stages of drug discovery
- Learn the concept of bioisosterism and drug resistance
- Describe physicochemical Properties and the techniques involved in QSAR
- Learn introduction to Bioinformatics and Cheminformatics
- Learn methods in molecular and quantum mechanics
- Explain various structure based drug design methods (Molecular docking, Denovo drug design)
- Learn the concept of pharmacophore and modelling techniques
- Explain the various techniques in Virtual Screening

5. Course Plan:

Component	**Unit**	**Topics or Coverage**

C1	Unit 1	Introduction, History of Drug Development, Basic pharmacodynamics and pharmacokinetics, Strategies for drug designing and drug development, Lead generation and Lead optimization Analogue and structure based methods, File format, conversion, Coordinate systems
	Unit 2	Identifying Cavities and Surface Matching, Shape Complementarity, Solvent-Accessible Surface, Connolly Surface, Lenhoff "Surface", Nussinov and Wolfson Method, Alpha Shapes.
C2	Unit 3	Docking and scoring methods for proteins-ligands, protein-protein, protein-DNA, DNA-ligand, Geometric Hashing, Generating a Coordinate System, Kuntz System, Clique detection, Docking**,** Search and its Dimensionality, Evolutionary Algorithms (EA), Tabu Search (TS), Hybrid Global- Local Search,Lamarckian GA (LGA)
	Unit 4	Docking Software: Dock, AutoDock, Flexx, GOLD, Optimization Technique: Gradient Descent**,** Approach, Simulated Annealing, Metropolis Algorithm, Genetic Algorithm, Receptor mapping and active site finding
	Unit 5	Introduction, Pharmacophore Modeling, Structure Based Drug Designing (SBDD), Ligand Based**,** Drug Designing (LBDD), Pharmacophore Generation, Hypogen Theory, HipHop Theory, Softwares Ex: Catalyst ect..

6. Text/Reference Books:

1. Drug Design: Structure and ligand-based approaches: Kenneth M.Merz, Dagmar Ringe, CharlesH.Reynolds.

2. Bioinformatics-from genomes to drugs (Vol.2- Applications Lengauer, Thomas (ed.).

3. Burger`s medicinal chemistry & drug discovery; Vol.-2(Drug discovery and drug development) Abraham, Donald J. (ed.)

4. Drug design : structure and ligand-based approaches: edited by Kenneth M. Merz, Dagmar Ringe, Charles H. Reynolds

5. Chemoinformatics; (Vol.-275 - Methods in molecular biology) : concepts, methods and tools for drug discovery : Bajorath, Jurgen (ed.)

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16. Clinical Biochemistry

1. Name of the Course and Code: Clinical Biochemistry (PE-AS-CBC516)

2. **LTP structure of the course:** 3-0-0

3. **Objective of the course:** Study of the important biomolcules like sugar, lipid, vitamin and minerals. This course will offer the scope of learning about structure, classification and important biological functions of these molecules. The function of these biomolcules will help to provide understanding the chemistry of living organisms and the molecular basis for the changes occurring in living cells. This course will also provide laboratory techniques that used to measure of these chemicals in blood, urine and other body fluids.

5. **Course Plan:**

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	Carbohydrates: Structure and functions, families of monosaccharides and structure of carbohydrates, stereoisomerism and mutarotation, derivatives of monosaccharides, disaccharides, trisaccharides and polysaccharides.
	Unit 2	Lipids: Structure and functions, classification of lipids, fatty acids and essential fatty acids, general structure and functions of major lipid subclasses, phosphoglycerides, sphingolipids, and steroids.

Component 2	Unit 3	Vitamins and Minerals: Definition, chemistry and functions of water and fat soluble vitamins, major trace minerals, their bound forms and functions.
	Unit 4	Study Beer-Lambert Law for absorption, Estimation of total and reducing sugars by spectroscopic method. Method of Estimation of serum cholesterol, creatine, uric acid, triacylglycerides, bilirubin and blood sugar.

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17. Infectious Disease Modeling

1. **Name of the Course and Code:** Infectious Disease Modeling (PE-AS-IDB517)

2. **LTP structure of the course:** 3-0-0

3. **Objective of the course:** To expose the B. Tech./M. Tech/ PhD students to the mathematical techniques of nonlinear dynamics and to use those to analyze the dynamics of any population, particularly a population that has been infected by a contagious agent.

4. **Outcome of the course:** Students would be able to analyze and model the dynamics of an infectious disease, and would be able to forecast the infection rate etc. for a population. Further, students would be able to master the techniques of nonlinear dynamics that are widely used in engineering, physics, chemistry, biology etc.

5. Course Plan:

Components	**Units**	**Topics for Coverage**	**Prerequisite**
	Unit 1	Review of Linear ordinary differential equations (ODE) and introduction to nonlinear ODE. Vector	

C1		fields and flows, One-Dimensional Flows, Flows on a line.	Exposure to ordinary differential equations.
	Unit 2	Bifurcations, two dimensional flows, linear systems, phase plane, limit cycles.	
C2	Unit 1	Logistic model, carrying capacity. Infectious diseases, SIR, SEIR, SIRD, SEIRD models.	
	Unit 2	Parameter calibration in infectious disease models. Simulating the models with real data.	

6. Text Book: Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry and Engineering by S. Strogatz, Taylor & Francis (1 January 2014).

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18. Materials Informatics

1. **Name of the Course and Code:** Materials Informatics **(PE-AS-MIN518)**

2. **LTP structure of the course: 3**-0-0

Objective of the course: This course has been designed to give a flavor of the theoretical approach as well as the experimental analysis of material's properties. The students will also be given knowledge about data collection and their scientific analysis for a better understanding of the fundamentals of material informatics. Knowledge of materials informatics is widely used nowadays in both industry and academia to simulate the various properties of materials and molecules.

Outcome of the course: Depending on the problem or needs of each case, the student must have sufficient criteria to select the most appropriate technique and interpret their results. The knowledge gained from this subject helps students optimize their material informatics research. The students must know how to study

materials' quantum mechanical properties from atomic to bulk. They also learn about applying DFT calculations to simulate materials properties using Wien2K and Quantum Espresso.

Course Plan

Component	Unit	Topics for Coverage
Component 1	Unit 1	Introduction to Density functional theory, Basic concepts in DFT: Hohenberg-Kohn theorem, Levy-Lieb constrained-search formulation of DFT, Kohn-Sham equation, and spin- polarized DFT. Exchange correlation functionals: local density approximation, hybrid exchange- correlation functional, self-interaction correction, etc.
	Unit 2	Basics of solids state physics and simulation process Bravais lattice, Crystal structure, reciprocal space, Bloch theorem, and Brillouin zone, Pseudopotentials: norm-conserving pseudopotential, nonlinear core correction, and project augmented wave technique, Numerical aspects of Kohn-Sham DFT: smearing, k-point sampling, Gaussian basis set, and plane- wave basis set, Ab initio molecular dynamics.
Component 2	Unit 3	Principle of X-ray diffraction (XRD), Importance of Rietveld refinement in XRD (fundamental), Lattice parameters, Structure analysis, Phase identification, Crystallite size analysis using Scherrer's formula, X-ray photoelectron spectroscopy (XPS), X-ray fluorescence (XRF), Energy dispersive X-ray analysis (EDAX). Advanced Microscopy Techniques for Nanomaterials Field emission scanning electron microscope (FESEM), Atomic force microscopy (AFM), Scanning tunneling microscopy (STM), Transmission electron microscopy (TEM), High- resolution transmission electron microscopy (HRTEM).
	Unit 4	Nanomaterials Electrical and Magnetic Characterization Techniques Measurement of resistivity by 4-probe method, Hall measurement, Measurement of magnetic properties of nanomaterials (Magnetic hysteresis and dielectric properties by LCR meter), Vibrating sample magnetometer.Vacuum Technologies Introduction, vacuum pumps: rotary Vane pumps, sorption

		pumps, Diffusion pumps, Turbo molecular pumps, Ion Pumps, cryogenic pumps, Vacuum gauges: Thermocouple gauge, McLeod gauge, Diaphragm gauge, Pirani gauge, and Penning gauge.

6. References:

• Delchar, T. A. (1993). Vacuum physics and techniques. Chapman and Hall.

• Density Functional Theory of Atoms and Molecules by Robert G. Parr and Weitao Yang.

• Many-Body Quantum Theory in Condensed Matter Physics by H. Bruus and K. Flensberg.

• A. K. Tyagi, Mainak Roy, S. K. Kulshreshtha and S. Banerjee, Advanced Techniques for Materials Characterization.

Component	**Unit**	**Topics for Coverage**

19. Instrumentation

1. Name of the Course Code: Instrumentation (PE-AS-INS519)

2. LTP structure of the course: 3-0-0

Component 1	Unit 1	Basics of vacuum science, creation of vacuum: rotary, diffusion, getter ion, turbo molecular, and cryo pumps, measurement of vacuum: Penning, Pirani, ionization gauges, B-A gauge.
	Unit 2	Designing a typical vacuum system, vacuum leak detection: helium leak detector, residual gas analyzer. Methods of producing thin films: PVD, CVD, sputtering, epitaxial films, film thickness measurement growth of thin films.
Component 2	Unit 3	Mechanical properties: adhesion and stress measurements, electrical properties, resistivity variation, Hall Effect, Optical properties: reflection, refraction, ellipsometry, reflecting and anti-reflecting films.
	Unit 4	Study of inter diffusion in thin films using XPS, AES, SIMS and RBS. Diffraction studies on thin films using LEED. Thin film morphological studies by SEM, STM and AFM, XRD, Raman,UV, Ultrafast , Magnetic and transport data analysis

3. Outcome of the course: On completion of the course, the student should be able to: discuss the differences and similarities between different vacuum based deposition techniques, evaluate and use models for nucleating and growth of thin films, asses the relation between deposition technique, film structure, and film properties, discuss typical thin film applications, motivate selection of deposition techniques for various applications.

4. Course Plan

6. Text Book/References:

1. Handbook of Thin Film Technology: Maissel and Glange (McGraw Hill).
2. Vacuum Technology: A. Roth (North Holland).
3. Fundamentals of Vacuum Techniques: Pipko, Pliskosky et al. (Mir Publishers).
4. Thin Films: K. L. Chopra.
5. Ultra High Vacuum Technology: D. K. Awasthi.
6. Thin Film Solar Cells: S.R. Das and S.P. Singh.

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20. Biomedical Engineering for Space

1. Name of the Course and Code: Biomedical Engineering for Space (PE-AS-BES520)

2. LTP structure of the course: 3-0-0

Course Plan

Component	Unit	Topics for Coverage
Component 1	Unit 1	Introduction to Humans in Space, Fundamentals of effects in micro-gravity, Exploration in Extreme Environments
	Unit 2	Bone changes in space, Muscle mechanisms, Motor Control Optimization, Musculoskeletal Dynamics and Control, Cardiovascular System, Cardiovascular Control
Component 2	Unit 3	Cardiovascular Simulation, Countermeasures and Artificial Gravity, Countermeasures and Artificial Gravity
	Unit 4	Extravehicular Activity (EVA), EVA II: Research

Reference books & Articles:

1. Human Anatomy Manual: The Skeleton." Gatesville, TX: Medical Plastics Laboratory, Inc., 1997
2. Beckers, Frank, Bart Verheyden, Andre E. Aubert. "Space Physiology." *Wiley Encyclopedia of Biomedical Engineering*. Hoboken, NJ: John Wiley and Sons, Inc., 2006. ISBN: 9780471740377
3. Schaffner, Grant. "Bone Changes in Weightlessness."

ii.

1. Brubakk, A. "Man in Extreme Environments." *Aviat. Space Env. Med.* (September 2000): A126-A130
2. Aubert, A.E., F. Beckers, and B. Verheyden. "Cardiovascular Function and Basics of Physiology in Microgravity." *Acta Cardiol* 60, no. 2 (2005): 129-151.
3. Diamandis, Peter H. "Countermeasures and Artificial Gravity." Chapter 12 in *Fundamentals of Space Life Sciences*. Edited by Susanne Churchill. Malabar, FL: Krieger Publishing Co., 1997. ISBN: 9780894640513.
4. Newman, Dava, and Michael Barratt. "Life Support and Performance Issues for Extravehicular Activity (EVA)." Chapter 22 in *Fundamentals of Life Sciences*. Edited by Susanne Churchill. Malabar, FL: Krieger Publishing Co., 1997. ISBN: 9780894640513.

Nanoelectromechanical systems (NEMs) - Molecular and Supramolecular Switches – Biosensors – Qdots – Nanoshells – Nanobiotix – Cancer detection – Drug Delivery using Nanoparticles and Molecular Carriers.

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21. Fluid Mechanics for Biological Systems

1. Name of the Course and Code: Fluid Mechanics for Biological Systems (PE-AS-FMB521)

2. LTP structure of the course: 3-0-0

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	Introduction to fluid mechanic's concepts, Fluids and non-fluids, Fluid Properties: viscosity, surface tension, compressibility etc. Classification of fluids. Basic Equations of fluid mechanics, Dimensional analysis.
	Unit 2	Different types of fluid flows, laminar and turbulent flow, transition from laminar to turbulent flow, laminar flow-annulus, laminar flow between parallel plates, measurement of viscosity. Development of boundary layer, estimates of boundary layer thickness, boundary layer equation, nature of turbulence, smooth and rough surface, boundary layer separation.
Component 2	Unit 3	Conservation Laws: Differential Analysis of the Conservation Laws. Conservation of Mass (continuity). Conservation of Momentum (Navier-Stokes). Conservation of Energy. Euler/Bernouilli equation.
	Unit 4	Heat and mass transfer. Physical, chemical and rheological properties of blood. Pulsatile Flow, Flow and pressure measurements, Models of Biofluid Flows, Basic Transport Phenomena in Biological System, Computational Biofluid Mechanics, Bioheat Transfers. Friction loss in flow in a tube, velocity distribution of aortic system, waveform of pressure and velocity in aorta, wave reflections and impedance in arterial segments, blood flow in veins and blood flow in capillaries. Mechanical analysis of circulatory systems, basic concept of myocardial mechanics, index of contractibility, fluid dynamics of aortic and mitral valves.

TEXT BOOKS

1. K. L. Kumar, "Engineering fluid mechanics", Eurasia Publishing House (P) Ltd., New Delhi, 1998.
2. D. H. Bergel, "Cardiovascular fluid dynamics"- Vol. I, Academic press, London & New York, 1972.
3. Biofluid Mechanics: An Introduction to Fluid Mechanics, Macrocirculation, and Microcirculation (Biomedical Engineering), by David Rubenstein, Mary D. Frame, Academic Press.
4. Biofluid Mechanics in Cardiovascular Systems (McGraw-Hill's Biomedical Engineering), Lee Waite
5. Biomechanics: Circulation (Fung, Y. C., Springer Verlag, 1996)
6. Biofluid Mechanics (Mazumdar, J. N., World Scientific, Inc., 1992)
7. Basic Transport Phenomena in Biomedical Engineering (Fournier, R. L. L., Taylor & Francis, Inc., 1998)
8. Physics in Biology & Medicine (Davidovits, P., Harcourt Academic Press, 2000)
9. David O. Cooney, An introduction to fluid, heat & mass transport process- Principles, Vol.1, Marcel Dekker Inc., New York, 1976.
10. Edwin N. Lightfoot, Transport phenomena and living systems – Biomedical aspects of momentum and mass transport, John Wiley, 1974
11. Ronald L. Fournier, Basic transport phenomena in biomedical engineering, Taylor Francis, 1998.

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22. Survival Analysis

1 Name of the Course: Survival Analysis (PE-AS-SAN522)

2 LTP structure of the Course: 3-0-0

3 Objective of the Course: This course provides an introduction to the analysis of lifetime data. The topics covered in this course are various hazard rate models, life tables, nonparametric estimators of survival function ad cumulative hazard function, Cox's hazard regression model for time independent and dependent covariates, and competing risk models. The inference for all these models will also be discussed.

4 Outcome of the Course: After successful completion of this course, the scholars will be able to understand the analysis of lifetime data and this will also help them learn the tools and techniques to be used in their research work subject to time to event data.

5 Prerequisite: Statistical Inference

6 Course Plan:

Component	Unit	Topics for Coverage
Component 1	Unit 1	Survival data, Concepts of time, order and random and hybrid censoring, Life distributions - exponential, gamma, Lognormal, Pareto, linear failure rate, Ageing classes - IFR, IFRA, NBU, NBUE, HNBUE and their duals, Bathtub failure rate. Parametric inference, point estimation, confidence Intervals, scores, tests based on LR, MLE.
	Unit 2	Life tables, failure rate, mean residual life and their elementary properties. Estimation of survival function - Actuarial estimator, Kaplan - Meier estimator, Estimation under the assumption of IFR/DFR.
Component 2	Unit 3	Semi-parametric regression for failure rate - Cox's proportional hazards model, partial likelihood, estimation and inference methods for the Cox models, time-dependent covariates, residuals and model diagnosis, functional forms of the Cox models, goodness-of-fit tests for the Cox models, Competing risk models, Repair models, Probabilistic models, Joint distribution of failure times Unconditional tests for the time truncated case, Tests for exponentiality, two sample nonparametric problem.
	Unit 4	Nelson-Aalen estimators, counting processes and martingales, modeling counting processes, Regression models for modeling multiple events, Frailty models, Shared frailty models, Identifiability of frailty models, Frailty regression models, Bivariate and correlated frailty models, Additive frailty models.

7 Text Books/References:

1 J.P. Klein, and M.L. Moeschberger, Survival Analysis: Techniques for Censored and Truncated Data , Springer, New York (1997).

2 D.R. Cox, and D. Oakes, Analysis of Survival Data, Chapman and Hall (1984).

3 J.D. Kalbfleish, and R.L.Prentice, The Statistical Analysis of Failure Time Data. New York: Wiley (2002).