Compulsory Courses / Fractals

Title	**Bioimaging**	Number	BBL7XX1 CSL7XX2
Department	Biosciences & Bioengineering and Computer Science & Engineering	L-T-P [C]	3-0-2 [4]
Offered for	M. Tech; PhD Program	Type	Compulsory
Prerequisite			

Objectives

The Instructors will provide students with fundamentals of bioimaging instrumentations, image processing and image analysis with emphasis on problems in the field of healthcare, agriculture and environment.

Learning Outcomes

The students are expected to have the ability to acquire basic knowledge and understanding of microscopic imaging and their applications in bioscience and bioengineering.

Contents

BBL7XX1 Instrumentation & Acquisition (2-0-2):

(fractal 1) *Image Formation:* Lenses; Optical aberrations, Koehler illumination; Diffraction; Point spread function; Resolution.(5 lectures)

Contrast Imaging Based Microscopy: Bright & Dark field, Phase contrast; Polarization; DIC, Fluorescent Probes & Proteins; Confocal; TIRF; Super-resolution (13 lectures)

Image Acquisition & Analysis: Cameras; Detectors; Basic Bio image analysis (5 lectures)

Imaging Modalities-X-rays, Magnetic and Gamma-rays in imaging and therapeutics, application of imaging in the field of biosciences (5 lectures)

Laboratory: Demonstration of microscopic imaging principles, contrast based microscopy techniques, Fluorescence based imaging, biological sample preparation & imaging, Image detectors, Bio image analysis, Biomedical Instrumentations, assignments on Bioimaging tools & techniques

CS7XX2 Bioimage computing (1-0-0):

(fractal 2) *Reconstruction:* Mathematical models of image regularity, random fields, practical data sampling and acquisition schemes (4 lectures)

Restoration: Deconvolution, degradation models for corrupted and missing data, Bayesian graphical modelling and inference, regression methods for filtering of bioimages (4 lectures)

Image segmentation, delineation & classification: Clustering, graph partitioning, classification, mixture models, expectation maximization, variational methods using geometric and statistical modelling, computer aided diagnosis (4 lectures)

Registration: Deformation models, optimization algorithms, 2D-3D registration, multi-modal registration (2 lectures)

Textbook

1. Murphy D.B., Fundamentals of Light Microscopy and Electronic Imaging, John Wiley & Sons, Inc., 2nd edition

Bankman, I., (2009), *Handbook of Medical Image Processing and Analysis*, 2nd Edition, Academic Press.

Self Learning Material

1. Basic of Light Microscopy & Imaging (The zeiss guide)

Preparatory Course Material

1. Debdoot Sheet, *Bioimaging*, NPTEL Course Material, Indian Institute of Technology Kharagpur, http://nptel.ac.in/courses/108105091/
2. Bishop, C., (2006), *Pattern Recognition and Machine Learning,* Springer.

Department	Bioscience & Bioengineering	L-T-P [C]	2–0–0 [2]
Offered for	M.Tech.	Type	Elective
Prerequisite	Nil		

Objectives

The Instructor will:

1. Introduce various technologies and relevant instrumentation applicable in genomics and transcriptomics research
2. Introduce the instrumentation and various technologies applicable in proteome analyses and provide context for generation and analyses of proteome data

Learning Outcomes

The students are expected to have the ability to:

1. Identify the right technology and method to be used in biological experiment design involving genomics and transcriptomics
2. Choose the correct proteomics technology and supporting instrumentation to answer a specific biological question

Contents

Genomics & Transcriptomics Technologies: Cell lysis & nucleic acid extraction; quality control; conventional nucleic acid sequencing; next-generation sequencing technologies & instrumentation, fragmentation, size selection & purification strategies; single molecule real-time sequencing technology; multiplexing strategies; strategies for aiding in analyses of data; microarray fabrication, hybridization & scanning equipment (14 Lectures)

Proteomics technologies: Protein extraction, fractionation, separation & purification, protein sequencing, isoelectric focusing, 1D & 2D gel electrophoresis based approaches, gel imaging equipment & analysis software, mass spectrometry for gel based proteomics, gel-independent separation & mass spectrometry methods, tandem mass spectrometry, quantitative proteomics (14 Lectures)

Textbook

1. Lesk A., (2017), *Introduction to Genomics*, 3rd Edition, Oxford University Press
2. Lovric, J., (2011), *Introducing Proteomics: From Concepts to Sample Separation, Mass Spectrometry and Data Analysis*. 11th Edition, Wiley-Blackwell.

Reference Books

1. Pevsner J., (2015), *Bioinformatics and Functional* Genomics, 3rd Edition, Wiley Blackwell.
2. Thangadurai D., Sangeetha J., (2015), *Genomics and Proteomics: Principles, Technoogies & applications*, 1st Edition, CRC Press
3. Twyman R., (2013), *Principles of Proteomics*, 2nd Edition, CRC Press

4. Conn P.M., [Ed.] (2003), *Handbook of Proteomic Methods*, Springer

Self-Learning Material

1. Vikash Kumar Dubey, *Proteomics & Genomics*, NPTEL Course Material, Department of Biosciences & Bioengineering, Indian Institute of Technology Guwahati, https://nptel.ac.in/courses/102103017/

2. S. Ganesh, *Functional Genomics*, NPTEL Course Material, Indian Institute of Technology Kanpur, https://nptel.ac.in/courses/102104056/

3. Sanjeeva Srivastava, *Proteomics: Principles and Techniques*, NPTEL Course Material, Department of Biosciences & Bioengineering, Indian Institute of Technology Bombay, https://nptel.ac.in/courses/102101007/6

Title	**Biomaterials engineering**	Number	BBL7XX0
Department	Bioscience & Bioengineering	L-T-P [C]	3-0-0 [3]
Offered for	M.Tech	Type	Compulsory
Prerequisite	None		

Objective

The Instructor will:

1. inspire future potential of bioengineering discipline

2. provide cutting edge knowledge and applications of biomaterials in tissue engineering, drug delivery, biomechanics and reconstitution various biological events

Learning Outcome

The students are expected to have the ability to:

understand how biomaterials are useful for various biotechnological and bioengineering applications

Contents

Background and definition of biomaterials: classes of materials used biotechnological applications and in medicine: polymers, metals, ceramics, natural materials and composites, biodegradable polymers in medicine: polymers, liposomes, hydrogels, silicone biomaterials and medical fibers, degradation of materials in the biological environment, types of polymer degradation. Influence of polymer properties on degradation, influence of biological environment on polymer degradation (14 lectures)

Surface engineering of biomaterials: biological testing of biomaterials: in vitro assessment of materials for tissue compatibility, in vivo assessment of tissue compatibility. Host reactions to biomaterials and their evaluations, the role of adsorbed proteins in tissue response to biomaterials. Cell, extra cellular matrix, and tissue interactions with biomaterials, inflammation, wound healing and foreign body response to biomaterials. Immune response to foreign materials. Toxicity, tumor genesis and biomaterials (14 lectures)

Microscopes for monitoring biomaterials and their dynamics: tirf and confocal, applications in drug delivery and nanomedicine, bioengineering concept to reconstitute cell like micro-chambers: flow-chambers and artificial cell, bioengineered platform for monitoring microtubule dynamics, bioengineered platform for monitoring microtubule motility and organization, bioengineered platform for monitoring microtubule force, reconstitution of kinesin transport using engineered biomaterials, applications in brain injury, repairing and future applications (14 lectures)

Textbook

Latest Research articles (ChemBioChem, Molecular Biosystem, AngewChem, ACS Chemical Biology, JACS, ChemComm, ACS Chemical Neuroscience etc.)

Self Learning Material

None

Preparatory Course Material

None

Title	**Statistical Techniques, Advanced Statistical Techniques**	Number	MAL7XX0 MAL7XX0
Department	Mathematics	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech	Type	Compulsory
Prerequisite	Nil		

Objectives:

The Instructor will:

1. Provide training in the analysis of the data from high dimensional biological data

2. Familiarizing the participants with the use of statistical tools and methodologies for analysing biological data

Learning outcomes:

The students are expected to:

1. Analyse data, be able to decide which data analysis tool to use

2. Implement statistical methods on real datasets

Contents

MAL7XX1: Statistical Techniques [1-0-0]

(fractal 1) probability models and sampling techniques, tests of hypotheses, stochastic process (14 lecture)

MAL7XX0: Advanced Statistical Techniques [2-0-0]

(fractal 2) estimation, mixture models and latent models, association and correlation analysis, regression analysis (28 lectures)

Textbook

1. Casella,G. and Berger,R., (2002), *Statistical Inference*, Cengage Learning.
2. Montogomery,D.C., Peck,E.A. and Vining,G.G., (2012), *Introduction to Linear Regression Analysis*, Wiley.
3. Medenhall,W., Beaver,R.J., Beaver, B.M., (2013), *Introduction to Probability and Statistics*, Cengage Learning.

Self Learning Material

1. Rosner,B., (2000), *Fundamentals of Biostatistics*, 5th Edition, Thomson Brooks/Cole.

2. Johnson,R.A., (2000), *Probability and Statistics for Engineers*, 6th Edition, Prentice Hall.

3.DeGroot,M.H., Schervish, M.J., (2002), *Probability and Statistics*, 3rd Rev. Edition, Addison-Wesley.

Preparatory Course Material Sen, S., Introduction to Biostatistics, NPTEL Course Material, Department of Biosciences and Bioengineering, Indian Institute of Technology Bombay, https://onlinecourses.nptel.ac.in/noc18_bt21/preview

Title	**Statistics and Data Analysis Lab**	Number	BBP7XX0
Department	Bioscience and Bioengineering	L-T-P [C]	0–0–2 [2]
Offered for	M.Tech	Type	Compulsory
Prerequisite	Nil		

Objectives

The Instructor will:

1. Provide training in the analysis of the data from high dimensional biological data

2. Familiarizing the participants with the use of statistical tools and methodologies for analysing biological data

Learning Outcomes

The students are expected to:

1. Analyse data, be able to decide which data analysis tool to use

2. Learn the latest programming languages

3. Implement statistical methods on real datasets

Laboratory Experiments

programming using pyspark/R, statistical modelling using real datasets, identification of biomarkers, application of ANOVA, genome-wide association analysis studies (linear and logistic regression), meta-analysis, population stratification techniques, survival analysis

Textbook

1. Casella,G. and Berger,R.L., (2002), *Statistical Inference*, 2nd Edition, Cengage Learning.

2. Montogomery,D.C., Peck,E.A. and Vining,G.G., (2012), *Introduction to Linear Regression Analysis*, 4th Edition, Wiley.

3. Medenhall,W., Beaver, R.J., Beaver, B.M., (2013), *Introduction to Probability and Statistics*, 14th Edition, Cengage Learning.

Self Learning Material

1. Rosner, B., (2000), *Fundamentals of Biostatistics*, 5th Edition, Thomson Brooks/Cole.

2. Johnson, R. A., (2000), *Probability and Statistics for Engineers*, 6th Edition, Prentice Hall.

3. DeGroot, M. H., Schervish, M. J., (2002), *Probability and Statistics*, 3rd Rev. Edition, Addison-Wesley.

Preparatory Course Material

Sen, S., Introduction to Biostatistics, NPTEL Course Material, Department of Biosciences and Bioengineering, Indian Institute of Technology Bombay, https://onlinecourses.nptel.ac.in/noc18_bt21/preview

Title	**Systems Biology**	Number	BBL7XX0
Department	**Bioscience and Bioengineering**	L-T-P [C]	3–0–2 [4]
Offered for	**M.Tech. 1st Year**	Type	Compulsory
Prerequisite			

Objectives

The Instructor will:

1. Provide an introduction to cellular and level systems biology with an emphasis on mathematical 22nalyse22r, synthetic biology, 22nalyse22r of genetic networks, genetic and metabolic engineering, and thermodynamics.

2. Cellular systems include genetic switches and oscillators, network motifs, genetic network evolution, and cellular decision-making.

Learning Outcomes

The students are expected to have the ability to:

1. Implement knowledge of important concepts related to the mathematical modelling of complex systems, especially metabolic networks, protein interaction networks and gene regulatory networks.

2. To apply them to model the 22nalyse22r of biological systems as well as develop strategies for manipulating them.

Contents

BBL7XX1 ***Mathematical Modelling & Simulations [1-0-0]:*** (fractal 1)Introduction to Modelling in Biomedicine, ODE 22nalyse22r of biochemical networks and cell populations, Boolean 22nalyse22r of biochemical networks, Agent-based 22nalyse22r of cell populations ad tissues (14 lectures)

BBL7XX2 ***Graph theory & Networks [1-0-0]:*** (fractal 2)Networks and graph theory, Network Measure, Scale-free networks, Biological networks, Modularity (14 lectures)

BBL7XX3 ***Genetic & Metabolic Engineering [1-0-0]:*** *(*fractal 3)Genetic Engineering, Metabolic Engineering (14 lectures)

Laboratory

Practical exercise of a mathematical model in the context of biological systems.

Network visualization tools: Cytoscape and Gephi.

Software packages: Boost, network, igraph for graph-theoretic computations

Textbook

1.Brian P. I., (2013) Mathematical Modeling in Systems Biology: An Introduction, MIT Press

2.Newman M. E. J. (2010), Networks: An Introduction, Oxford University Press.

3.Nesbeth D. N. (2016), Synthetic Biology Handbook, CRC Press.

Self Learning Material

1.Klipp E (2009) Systems biology : a textbook. Wiley-VCH

2.Department of Biological Engineering, MIT, https://be.mit.edu/research-areas/systems-biology

Preparatory Course Material

1. Department of Biotechnology, Indian Institute of Technology Madras, https://nptel.ac.in/noc/individual_course.php?id=noc18-bt22

Title	**Biosensors**	Number	**BBL7XX1** **EEL7XX2**
Department	Bioscience & Bio-engineering and Electrical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech	Type	Elective
Prerequisite			

Objectives

The Instructor will:Provide background on biosensors, their types, fabrication, characterization, & applications.

Learning Outcomes

The students are expected to have the ability to:

1. Understand the design and working of various biosensors
2. to design a sensor based on the figures of merit**Contents**

BBL7XX1: Types of biosensors and their characterization [1-0-0]

(fractal 1) Introduction to biosensors, their applications, importance & relevance in the field of healthcare, agriculture and environment monitoring (4 lectures)

Basic principles and types of sensors: Protein/antibody-based sensors: surface chemistry. Electrochemical and optical sensors, Redox-enzyme, Optical methods: UV/Vis/IR, fluorescence, luminescence, fibre optics, surface plasmon resonance, and mass based sensors Analytical methods chromatography, spectrophotometry, electrochemical characterization (10 lectures)

EEL7XX2: Micro-fabrication technologies, sensor signals, interfacing and read out electronics [1-0-0]

(fractal 2) *Introduction to micro-system fabrication technologies*: optical lithography, etching, metallization, CVD, LIGA, DRIE, micro-molding, surface and bulk micromachining and packaging. Case studies related to high aspect ratio structures e.g. micro-channels, Microarrays, Micro-reactors, microfabricated PCR, lab on chip, *Biosensor interfacing*: sources of noise, interfacing circuitry and read out electronics (14 Lectures)

Textbook:

1. Anthony, T., Isao, K., Wilson, G.S., (2017) *Biosensors: Fundamentals and applications*, Oxford University Press.

Reference book:

1. Benica, F-G., (2012) *Chemical Sensors and Biosensors-Fundamentals and applications*, 12th edition, John-Wiley & Sons Ltd.
2. Tai-Ran Hsu, (2017), *MEMS & Microsystems Design and Manufacture*, Indian Edition, Tata McGraw-Hill

Self Learning Material 1.Dr. Mainak Das, Department of Bioscience & Bioengineering, IIT Kanpur, https://nptel.ac.in/courses/102104062/19

1. Dr. K Uma Mahshwari, Sastra University https://nptel.ac.in/courses/118106019/

Program Elective Set 1

Bioimaging & Health Informatics

Title	**Fundamentals of Neuroscience**	Number	BBL7xx0
Department	Bioscience & Bioengineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech	Type	Elective

Objectives

The Instructor will:

1.Provide introduction to neuroanatomy for engineers and cognitive neuro anatomists

2. Provide Hands-on training is provided in the fundamentals of neuroanatomist structures and functions. Understanding of which has diverse applications in disease diagnostics by imaging.

Learning Outcomes

The students are expected to have the ability to: understand areas of application based on the understanding of neuroanatomist structures and their association in some diseases.

Contents

Why are we interested in the brain: Diseases of the nervous systems (14 lectures): Schizophrenia, Depression, Diseases of Neural Degeneration: Alzheimer's, Senile Dementia of the Alzheimer's Type, Diagnosed as memory loss with inability to complete activities of daily living, Macroanatomy: Degeneration of higher cortices, Microanatomy: Amyloid plaques and tangles, Lou Gehrig/ALS, diseases of the Basal Ganglia, Huntington's, Parkinson's, Plasticity and Disease,

Diseases of Deafferentation (7lectures), Multiple Sclerosis, Phantom pain/central pain, Diseases of Vasculature, stroke, Migraine. Diseases and Neural Dynamics, Language Specific Learning Deficit, Association of Structure and Function,

Cerebellar anatomy and its disorders (7lectures): motor disorders, Stumbling gate, psychiatric disorders, Pitch discrimination, language ability, Tactile perception, Deficits are not Trivially Localized,

Deficits of NT systems (14 lectures): Depression, Schizophrenia, Phantom Limb, Alzheimer's and the Brain

Textbook

1. Kandel,E., (2012), *Principles of Neural Science*, 5th Edition, Elsevier

2. Zigmond M (2012), *Fundamental Neuroscience*, 4th Edition Elsevier

Reference Books

1. Lodish B, Kaiser K (2016), *Molecular Cell Biology*, 8th Edition, WH Freeman

Online Course Material

1. Constantine-Paton M, *9.013J / 7.68J Cell and Molecular Neurobiology*, Spring 2008, MIT OpenCourseWare Massachusetts Institute of Technology, https://ocw.mit.edu. License: Creative Commons

Title	**Digital Image Analysis**	Number	**CSL7XX0**

Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for		Type	Elective
Prerequisite	None		

Objectives

The Instructor will:

1. Introduce the origin and formation of digital imaging.

2. Develop the understanding of different types of image processing and analysis for different purposes.

3. Show how to develop modular systems for image analysis through hands-on application development.

Learning Outcomes

The students are expected to have the ability to:

1. Enhance image in spatial and frequency domain.

2. Implement various aspects of image segmentation, compression, and content analysis.

Contents

Digital Image Fundamentals: Image 27nalyse27r, Sampling and Quantization, Imaging Geometry,Digital Geometry, Image Acquisition Systems, Different types of digital images. (4)

Bilevel Image Processing: Basic concepts of digital distances, distance transform, medial axis transform, component 27nalyse27r, Histogram of grey level images, Optimal thresholding. (5)

Images Enhancement: Point processing, enhancement in spatial domain, enhancement in frequency domain. (5)

Detection of edges and lines in 2D images: First order and second order edge operators,multi-scale edge detection, Canny's edge detection algorithm, Hough transform for detecting lines and curves. (5)

Color Image Processing: Color Representation, Laws of color matching, chromaticity diagram, color enhancement, color image segmentation, color edge detection. (5)

Image compression: Lossy and lossless compression schemes, prediction based compression schemes, vector quantization, sub-band encoding schemes, JPEG compression standard. (6)

Segmentation: Segmentation of grey level images, Watershed algorithm for segmenting grey level image. (5)

Morphology: Dilation, erosion, opening, closing, hit and miss transform, thinning, extension to grey scale morphology. (4)

Feature Detection: Fourier descriptors, shape features, object matching/features(3)

Textbook:

1. Gonzalez and Woods, Digital Image Processing, Prentice-Hall.

2. Fundamentals of Digital Image Processing by Anil K. Jain.

Self Learning Material

NPTEL: Digital Image Processing

https://nptel.ac.in/courses/117105079/

Title	**Machine Learning-1**	Number	**CSL7XX0**
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech. 1st Year, Ph.D. 1st Year	Type	Compulsory
Prerequisite	None		

Objectives

The Instructor will:

1. Provide motivation and understanding of the need and importance of Machine Learning in today's world

2. Provide details about various algorithms in Machine Learning

Learning Outcomes

The students are expected to have the ability to:

1. Develop a sense of Machine Learning in the modern context, and independently work on problems relating to Machine Learning

2. Design and program efficient algorithms related to Machine Learning, train models, conduct experiments, and deliver ML-based applications

Contents

CSL7XX1: Machine Learning I: Supervised Learning 1-0-0[1]

Introduction: Motivation, Different types of learning, Linear regression, Logistic regression (2 lectures)

Gradient Descent: Introduction, Stochastic Gradient Descent, Subgradients, Stochastic Gradient Descent for risk minimization (2 lectures)

Support Vector Machines: Hard SVM, Soft SVM, Optimality conditions, Duality, Kernel trick, Implementing Soft SVM with Kernels (4 lectures)

Decision Trees: Decision Tree algorithms, Random forests (2 lectures)

Neural Networks: Feedforward neural networks, Expressive power of neural networks, SGD and Backpropagation (3 lectures)

Model selection and validation: Validation for model selection, k-fold cross-validation, Training-Validation-Testing split, Regularized loss minimization (1 lectures)

CSL7XX2: Machine Learning I: Unsupervised Learning and Generative Models 1-0-0[1]

Nearest Neighbour: k-nearest neighbour, Curse of dimensionality (1 lecture)

Clustering: Linkage-based clustering algorithms, k-means algorithm, Spectral clustering (3 lectures)

Dimensionality reduction: Principal Component Analysis, Random projections, Compressed sensing (2 lectures)

Generative Models: Maximum likelihood estimator, Naive Bayes, Linear Discriminant Analysis, Latent variables and Expectation-maximization algorithm, Bayesian learning (5 lectures)

Feature Selection and Generation: Feature selection, Feature transformations, Feature learning (3 lectures)

CSL7XX3: Machine Learning I: Computational Learning Theory and Deep Neural Networks 1-0-0[1]

Statistical Learning Framework: PAC learning, Agnostic PAC learning, Bias-complexity tradeoff, No free lunch theorem, VC dimension, Structural risk minimization, Adaboost (7 lectures)

Foundations of Deep Learning: DNN, CNN, RNN, Autoencoders (7 lectures)

Textbook:

1. Shalev-Shwartz,S., Ben-David,S., (2014), Understanding Machine Learning: From Theory to Algorithms, Cambridge University Press

Reference Books:

2. Mitchell Tom (1997). Machine Learning, Tata McGraw-Hill

Self Learning Material

3. Department of Computer Science, Stanford University, https://see.stanford.edu/Course/CS229

Title	**Image Sensor Design and Applications**	Number	**EEL7XX0**
Department	Electrical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	B.Tech. IV, M. Tech, Ph.D.	Type	Elective
Prerequisite	Analog electronics		

Objectives

The Instructor will:

1. Introduce the design and analysis of CMOS image sensors.

2. Explain the readout electronics behind the camera.

3. Provide the knowledge of performance measures and tradeoffs involved in the camera design.

Learning Outcomes

The students are expected to have the ability to:

1. Design and develop CMOS image sensor including the sensing mechanism and signal chain of the camera.
2. Implement different techniques required for high dynamic range camera, high frame rate, low noise camera, time of flight 3D cameras etc.

Contents

Introduction to photodetectors: Photodiode and photogate, photocurrent, dark current, quantum efficiency, spectral response and photo-conversion principles (5 Lectures).

Introduction to Charge coupled devices and CMOS image sensors: Operation, performance metrics, noise and its types, spatial resolution and modulation transfer function. Concept of exposure triangle including aperture, shutter speed and ISO, color filters, Bayer pattern, Shutters and its types, motion blur, hard and soft reset, Introduction to imaging optics (8 Lectures).

Readout electronics and image sensor characterization: Readout and its types, design tradeoffs and challenges, analysis of the signal path behind the camera, variable gain amplifiers, double sampling circuits, ADCs, reference circuits including BGR and LDO, clock generation circuits including PLL and delay elements, floor planning, placement and routing, image sensor characterization. Introduction to wire bonding, packaging, lens and color filters for product level design (15 Lectures).

Emerging trends: High speed cameras, high dynamic range cameras, 3D cameras for background light subtraction and depth estimation. Concepts of Polarization imaging, low light imaging, machine vision, backside illumination, stacked technology, target tracking (10 Lectures).

Color Processing: Color demosaicing, color correction and white balance (2 Lectures).

Applications: Smart city,health care, autonomous vehicles, sports, motion detection, surveillance (2 Lectures).

Textbook

1. Jun Ohta, (2007), Smart CMOS Image sensors and Applications, CRC press.

Self Learning Material

1. O. Yadid Pecht and R. E. Cummings (2004), CMOS imagers: From Photo transduction to Image processing, Springer.

2. Image sensors blog http://image-sensors-world.blogspot.com/

Preparatory Course Material

1. El Gamal, Abbas, and Helmy Eltoukhy (2005) “CMOS image sensors.” IEEE Circuits and Devices Magazine vol. 21, no. 3, pages 6-20.

2. Fossum, Eric R. (1997) “CMOS image sensors: Electronic camera-on-a-chip.” IEEE transactions on electron devices vol. 44. No. 10, pages 1689-1698.

Title	**Introduction to Medical Physics**	Number	**PHL7XX0**
Department	Physics	L-T-P [C]	2–0–0 [2]
Offered for		Type	Elective
Prerequisite			

Objectives

The instructor will

1. Introduce physics concepts and principles relevant for medicine and health 2. Provide the introduction of modern diagnostic tools and various technology to medical research and to the healthcare arena in general that is set to revolutionize the way we cure diseases.

Learning Outcomes

Aspects of physics with engineering for biological applications

1. Contribution of physics in the development of medical diagnostics

Contents

PH7XX1 (Radiological imaging techniques) [1-0-0]

(a) Physics in Medical research: Interaction of radiation with matter, Interaction of photons with tissues, molecules, cells and organs, Elastic and inelastic scattering, Thomson and

Compton Scattering. (6 lectures)

1. Radiological imaging: X-ray imaging and computerized Tomography (CT), Radioisotope imaging, Positron–emission Tomography, Introduction to the image analysis. (8 lectures)

PH7XX3 (Physics in Therapeutics) [1-0-0] (a) Plasma for Medicine: Introduction of low temperature plasma technology to medical research, plasma chemistry, fundamentals of non-equilibrium plasmas and cell biology. Cold plasma applications in the inactivation of pathogens, anti-bacterial coatings, wound healing, electrosurgery, cancer treatment and dentistry. (10 lectures) (b) Nuclear Medicine: Radioactivity, Production of radionuclides, Radiation therapy for cancer treatment. (4 lectures)

Textbook

1. Cho, Z-H., Jones, J. and Singh, M., Foundations of Medical Imaging, 1st Edition Wiley Interscience, 1993

2. Pryma, D. A., Nuclear Medicine, 1st Edition, Oxford University Press, 2015

3. Murphy, D. B. and Davidson, M. W., Fundamental of Light Microscopy and Electronic Imaging, 2nd Edition, Wiley-Blackwell, 2012

Reference Books

1. Toyokuni, S., Ikehara, Y., Kikkawa, F. and Hori, M. (2018), Plasma Medical Science, 1st Edition, Academic Press.

Self-Learning Material

1. Department of Electrical Engg, IIT Kharagpur, https://nptel.ac.in/courses/108105091/

2. Jasanoff, A., MIT Open courseware, Noninvasive Imaging in Biology and Medicine,

https://ocw.mit.edu/courses/nuclear-engineering/22-56j-noninvasive-imaging-in-biology-and

medicine-fall-2005/index.htm.

Preparatory Course Material

1. Department of Physics, IIT Delhi, https://nptel.ac.in/syllabus/115102017/.

Title	**Principles of Drug Discovery**	Number	BBL7XX1 CSL7XX1 CSL7XX2
Department	Bioscience & Bioengineering and Computer Science and engineering	L-T-P [C]	3-0-0 [2]
Offered for	M.Tech	Type	Elective
Prerequisite	None		

Objective

The Instructor will:

1. focus on route of drug design and discovery

Learning Outcome

The students are expected to have the ability to:

1. understand the principles of drug design and development

Contents

BBL7XX1: Principles of Drug Discovery [1-0-0]

(fractal 1)drug targets, pharmacokinetics, administration and dosing, drug testing: *in vivo and in vitro*, drug discovery: natural lead, synthetic lead, combinatorial synthesis, pharmacokinetics based drug design, chemical development, process development, toxicology, pharmacology, drug metabolism, clinical trials, commercialization (14 lectures)

CSL7XX0: Machine Learning-1 [2-0-0]

(fractal 2) introduction, gradient descent, support vector machines, decision trees, neural networks (14 lectures)

(fractal 3) nearest neighbour, clustering, dimensionality reduction, generative models, feature selection and generation (14 lectures)

Textbook

1. Stromgaard,K., Krogsgaard-Larsen,P., Madsen,U., *Drug Design and Discovery*, 5th Edition, CRC Press

Self-Learning Material

1. Department of Computer Science, Stanford University
https://see.stanford.edu/Course/CS229

Preparatory Course Material

Title	**Introductory Chemical Biology**	Number	BBL7XX0
Department	Bioscience & Bioengineering	L-T-P [C]	3-0-0 [3]
Offered for	M.Tech	Type	Elective
Prerequisite	None		

Objective

The Instructor will:

1. Build fundamental concept of interdisciplinary science, specially chemical biology

Learning Outcome

The students are expected to have the ability to:

1. Understand the importance of interdisciplinary sciences and its applications in bioengineering fields

Contents

Introduction: background and definition of chemical biology, overview of chemical biology, allied fields and their link with chemical biology, overview of protein structure and protein-protein interactions (14 lectures)

Biomolecular-drug interaction: key discoveries in the field of chemical biology, few examples and journey through those discoveries, the use of unusual amino acids to probe biomolecular conformation, the use of novel fluorescence probe and applications, sirna as therapeutics, small molecule kinase inhibitors, gtp analogues as potential regulators for microtubule dynamics (14 lectures)

Imaging: applications of small molecule as a probe for *in vivo* imaging, chemical tools for perturbation of protein-protein interactions, chemical platforms for protein-protein and protein-nucleic acid interactions (14 lectures)

Textbook

1. Chemical Biology: From Small Molecules to Systems Biology and Drug Design (Willey), Editor(s): Profs. Stuart L. Schreiber, Tarun M. Kapoor and Günther Wess Nature Chemical Biology, 2010, 6, 847-853

Self Learning Material

None

Preparatory Course Material

None

Program Elective Set 2

Multi-'Omics'

Title	**Omics Databases**	Number	BBL 7XX0
Department	Bioscience & Bioengineering	L-T-P [C]	1–0–0 [1]
Offered for	M.Tech.	Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. Introduce the biological databases commonly encountered in omics research and will highlight how different data types are used across biology

Learning Outcomes

The students are expected to have the ability to:

1. Store / retrieve biological data in / from relevant databases and process it for analyses

Contents

Biological Databases: Sequence databases, gene expression databases, sequence read archives, peptide databases, metabolite libraries, phenomic databases, data file formats, conversion between formats, considerations for data submission to databases, considerations for using data retrieved from databases, data quality control, **[data warehousing and integration, anonymizing data*]** (14 lectures)

Textbook

1. Byron K., Herbert K.G., Wang J.T.L, (2016), *Bioinformatics Database Systems*, CRC Press
2. Srivastava C., (2019), *Informatics in Proteomics*, CRC Press

Reference Books

1. Bergeron B., (2016), *Bioinformatics Computing*, Pearson

Self-Learning Material

None

*Will be covered by CSE Department

Title	**Introduction of Data Science**	Number	MAL7XX0
Department	Mathematics	L-T-P [C]	1–0–0 [1]
Offered for	M.Tech.	Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. Introduce the basics of data science and its underlying concepts.

2. Introduce data processing, manipulation and cleaning techniques.

Learning Outcomes

The students are expected to have the ability to:

1. Acquire familiarity with the basic concepts of data science.

2. Distinguish between different kinds of data and data governance.

3. Understand the preparation and processing of the data.

Contents [14 Lectures] Data preparation, Data pre-processing, Data Cleaning, Data Integration, Data Transformation, Data Reduction, Redundancy Removal, Data storage, Data Handling, Querying Data, Data Representation and Exploration, Big Data.

Text Books

1. Kotu, V. and Deshpande, B. (2018) Data Science: Concepts and Practice, Morgan Kaufmann.

2. Saltz, J.S. and Stanton, J.M. (2017) An Introduction to Data Science, SAGE Publications.

3. Kelleher, J.D., and Tierney, B. (2018) Data Science, MIT Press.

Reference Books

1. Moreira, J., Carvalho, A. and Horvath, T. (2018) A General Introduction to Data Analytics, John Wiley & Sons.

2. Mayer-Schonberger, V. and Cukier, K., (2013) Big data: The essential guide to work, life and learning in the age of insight, John Murray Publications.

Online course Material

Not Available

Title	**Data Management (Fractal of Software and Data Engineering)**	Number	CSL7XX2
Department	CSE	L-T-P [C]	1–0–0 [1]
Offered for	M.Tech.	Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. Discuss techniques to manage a large amount of data

Learning Outcomes

The students are expected to have the ability to:

1. Design complex end-to-end data pipeline for data processing

2. Critically identify and use the tools for data handling and management

Contents

CSL7XX2 Data Management 1-0-0 [1]

Data Management: Structured data, relational database management, unstructured data, semi-structured data, Nosql database management (mongodb), column database, graph database, XML, JSON, HDFS, Handling drift in data, sensor data reliability at software and algorithmic level, sensor data analysis techniques (14 lectures)

Textbook

1. Bass L., Clements P., Kazman R., (2012), Software Architecture in Practice, 3rd edition, Addison-Wesley Professional

2. Martin K., (2017), Designing Data-Intensive Applications: The Big Ideas Behind Reliable, Scalable, and Maintainable Systems, 1st Edition, O'Reilly Media

Self Learning Material

1. Tylor,R.N., Medvidovic,N. and Dashofy,E.M., (2014), Software Architecture Foundation: Theory and Practice, Wiley
2.

Preparatory Course Material

1. IEEE Transactions on Knowledge and Data Engineering

2. International Conference on Data Engineering

Title	**Microarray Data Analysis**	Number	BBL7XX0
Department	Bioscience & Bioengineering	L-T-P [C]	2–0–0 [2]
Offered for	M.Tech.	Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. Provide background to 41nalyse microarray technology/RNA sequencing gene expression data.
2. Familiarize the students with the use of advanced tools and methodologies for 41nalyse41r microarray/RNA seq expression data

Learning Outcomes

The students are expected to have the ability to:

1. Understand the structure of the data, the statistical procedures used to remove the inherent noise present in the data (pre-processing of the data)

2. Decide which data analysis tool to use

Contents

DNA Microarray: Gene expression biology, DNA microarrays and their importance, types of microarrays- two-channel cDNA arrays, single-channel Affymetrix genechips, microarray platforms, Designing a microarray experiment-The basic steps

Microarray Databases: NCBI and microarray data management, GEO (Gene Expression Omnibus), Array Express, The benefits of GEO and Array Express.

Microarray Data Normalization: Importance of microarray data pre-processing, Background correction, Data normalization, Measuring dissimilarity of expression pattern using dissimilarity measures

Microarray Data Analysis: Identification of differentially expressed genes- using statistical and computational approaches, Classifying samples from two populations using k-nearest 41nalyse41r classifier, Support Vector Machines and their applications, For grouping co-expressed genes- Kmeans Clustering, Hierarchical Clustering.

Visualization and Functional Analysis: Bio-molecular pathways, gene ontology, enrichment analysis, hypergeometric distribution, calculation of P-Value, hypothesis testing, multiple hypothesis testing

Textbook

1. Draghici, S., (2012), *Statistics and Data Analysis for Microarrays Using R and Bioconductor*, 2nd Edition, Chapman & Hal/CRC.

Reference Books

1. Knudsen, S., (2004), *Guide to Analysis of DNA Microarray Data*, John Wiley & Sons.
2. Stekel, D., (2002), *Microarray Bioinformatics*, Cambridge University Press.
3. Draghic, S., (2002), *Data Analysis tools for DNA Microarray*, Chapman and Hall/CRC Press.

Online Course Material

1. Srivastava, S., *Microarray Data Analysis*, Department of Bioscience and Bioengineering, Indian Institute of Technology Bombay, http://nptel.ac.in/courses/102101054/35

Title	**RNA Sequencing Data Analysis**	Number	BBL7XX0
Department	Bioscience & Bioengineering	L-T-P [C]	2-0-0 [2]
Offered for	M.Tech.	Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. Illustrate the intricacies involved in choosing the right RNA sequencing platform and will highlight the key steps of data analysis

Learning Outcomes

The students are expected to have the ability to:

1. Analyse an RNA sequencing dataset and draw biological meaning from the data

Contents

Introduction to RNA Sequencing Data: Sequencing chemistries, choosing the right method for an application, principal considerations while designing an RNA sequencing experiment

Quality Control: Sequence quality scores, pre-processing steps & considerations, FastQC, filtering & trimming of low-quality reads, detecting contaminants, removing adapters, red flags & troubleshooting

Reference mapping: Alignment tools, assessment of alignment statistics, manipulating alignments, visualizing alignments

De novo assembly: Transcriptome reconstruction & inherent complexities, pre-processing considerations for de novo assembly, de Bruijn graph, assembly tools, R & bioconductor for data analysis

Gene expression analysis: Annotation, counting reads per transcript, differential gene expression, importance of biological & technical replicates, count distributions, normalization, visualizing differential gene expression, graphics & plot types

Detecting Non-coding RNAs: Methods for detecting non-coding RNAs, sRNAs, miRNAs, piRNAs, endo-siRNAs, exo-siRNAs, snoRNAs, snRNAs

Applications of RNA sequencing: Transcriptome response profiling, finding splice variants, detecting allele specific expression in disease

Textbook

1. Korpelainen E., Tuimala J., Somervuo P., Huss M., Wong G., (2015), *RNA-Seq Data Analysis: A Practical Approach*, CRC Press

2. Wang X., (2016), *Next-Generation Sequencing Data Analysis*, CRC Press

Reference Books

Review & research articles as prescribed by the Instructor

Self-learning Material None

Title	**Algorithms in Biology**	Number	BBL7XX0
Department	Bioscience & Bioengineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech	Type	Elective
Prerequisite	Nil		

Objectives:

1. To develop an understanding of the main algorithmic approaches used in solving computational problems that arise in the analysis of biomolecular data (such as DNA/RNA/amino acid sequences, mass spectra of proteins, whole genomes, or gene expression levels).

Learning outcomes:

The students are expected to:

1. Understand various algorithms related to biological data analysis.
2. Develop new efficient algorithm to solve biological data.

Contents

Algorithms and Complexity: What is an algorithm?, Biological Algorithm versus Computer Algorithms, The change problem, Correct versus Incorrect Algorithms, Recursive Algorithms, Iterative versus Recursive Algorithms, Fast vs Slow Algorithms, Big-O Notation, Algorithm Design Techniques, Tractable versus Intractable Problems *(10 lectures)*

Greedy Algorithms: Genome Rearrangements, Sorting by Reversals, Approximation Algorithms, Breakpoint: A different face of greed, A greedy approach to motif finding *(10 lectures)*

Dynamic programming algorithms: The power of DNA sequence comparison, the change problem revisited, the manhattan tourist problem, edit distance and alignments, longest common subsequences, global sequence alignment, local sequence alignment, alignment and gap penalties, multiple alignment, gene prediction. *(10 lectures)*

Clustering and Trees: Gene expression analysis, Hierarchical Clustering, *k*-means clustering, clustering and corrupted cliques, evolutionary trees, distance based tree reconstruction, Evolutionary trees and hierarchical clustering, small parsimony problem, large parsimony problem *(7 lectures)*

Gene selection algorithms: SAM, eBayes, Limma, CFS, mRMR, MRMS *[5 lectures]*

Textbook

1. Jones N. C. ,Pevzner P. A. (2014), An Introduction to Bioinformatics Algorithms, MIT Press

Reference Books

1. Mitra S. and Acharya T. (2003), Data Mining: Multimedia, Soft Computing, and Bioinformatics, New York: John Wiley
2. Mitra S., Datta S., Perkins T. and Michailidis G. (2008), Introduction to Machine Learning and Bioinformatics, New York: Chapman & Hall/CRC Press.

Online Course Material : None

Title	**Proteomics Data Analysis**	Number	BBL7XX0
Department	Bioscience & Bioengineering	L-T-P [C]	2–0–0 [0]
Offered for	M.Tech.	Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. Introduce the biological databases commonly encountered in omics research and will highlight how different data types are used across biology

Learning Outcomes

The students are expected to have the ability to:

1. Store / retrieve biological data in / from relevant databases and process it for analyses

Contents

Mass spectrometry for proteomics: Basic principles, ionization methods, mass analyzers & mass spectrometers, analysis of MS data, analysis of MS/MS data, simple vs complex samples (18 lectures)

Case studies: Qualitative proteomics, differential proteomics, detecting post-translational modifications, interactomics (10 lectures)

Textbook

1. Lovric, J., (2011), *Introducing Proteomics: From Concepts to Sample Separation, Mass Spectrometry and Data Analysis*. 11th Edition, Wiley-Blackwell.

Reference Books

1. Twyman R., (2013), *Principles of Proteomics*, 2nd Edition, CRC Press
2. Conn P.M., [Ed.] (2003), *Handbook of Proteomic Methods*, Springer

Online Course Material

1. Sanjeeva Srivastava, *Proteomics: Principles and Techniques,* NPTEL Course Material, Department of Biosciences & Bioengineering, Indian Institute of Technology Bombay, https://nptel.ac.in/courses/102101007/6

Title	**Microbial Genomes & Microbiomes**	Number	BBL7XX0
Department	Bioscience & Bioengineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech.	Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. Illustrate the various methods applicable in the generation, analysis and interpretation of microbial genome sequencing data

2. Outline the methods involved in determining the microbiome and assessing its importance in health, environment and agriculture

Learning Outcomes

The students are expected to have the ability to:

1. Determine the best possible methods to determine the sequence of bacterial genomes with naturally varying properties.

2. Be acquainted with the microbiomes associated with specific niches, methods to study them and infer what it means to have a specific microbiome in a given environment

Contents

Introduction to microbial genomes: Prokaryotic genome anatomy, Extrachromosomal elements, Separation (4 lectures)

Genome sequencing: Timeline of DNA sequencing technologies, Explosive abundance of Genomic Data, Problems with genome assembly and solutions, Coding sequence prediction, Methods of gene prediction, Pathways and metabolic models (8 lectures)

Functional & Comparative Genomics: Experimental annotation, Gene expression profiling, Interactome,Genome alignment, Genomic phylogeny, Pan-genomics (10 lectures)

Genome evolution: Genomic islands, Genome plasticity, Resistome, Molecular epidemiology, Minimal genome concept, Synthetic genomes, Genomic alterations (10 lectures)

Microbiomes: Introducing metagenomics, detecting unculturable microbes, the human microbiome project, 16S based microbiome analysis, metagenome shotgun sequencing, importance of the microbiome in health, applications of microbiome sequencing in agriculture & the environment

Textbook

1. Brown T.A. (2007) *Genomes 3,* Blackwell publications

2. Fraser C.M., Read T.D., Nelson K.E., (2004), *Microbial Genomes*, Humana Press

Reference Books

2. Review & Research articles as prescribed by the Instructor

Online Course Material Ganesh S., *Functional Genomics,* NPTEL Course Material, Department of Biological Sciences and Bioengineering, Indian Institute of Technology, Kanpur, http://nptel.ac.in/courses/102104056/

Title	**Metabolomics**	Number	BBL7XX0
Department	Bioscience & Bioengineering	L-T-P [C]	2–0–0 [1]
Offered for	M.Tech.	Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. Introduce metabolomics as a discipline highlighting some methods for data generation, analysis and interpretation

Learning Outcomes

The students are expected to have the ability to:

1. Choose the appropriate method to qualitatively or quantitatively analyze the metabolome from different biological samples

Contents

Metabolomics Technologies & Data analysis [14 lectures]: Mass spectrometry for metabolite profiling, liquid & gas chromatography separation technologies; capillary electrophoresis based separation technology; nuclear magnetic resonance in profiling; single cell metabolomics, processing of data for analysis, statistical analysis, lifestyle disease biomarker identification, lipidomics

Applications: Clinical samples, extraction methods, sample preparation, metabolic markers of disease, comparative metabolomics, metabonomics

Textbook

1. Fan T.W.M., Lane A.N., Higashi R.M., [Eds], (2012), *The Handbook of Metabolomics*, Springer

Reference Books

2. Sussulini A., [Ed] (2017), *Metabolomics: From Fundamentals to Clinical Applications*, Springer

Online Course Material

None

Program Elective Set 3

Biological Systems & Biosensors

Title	**Experimental design for biologists**	Number	BBN7XX0
Department	Bioscience and BioEngineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech	Type	Compulsory
Prerequisite	Nil		

Objectives

The Instructor will:

1. Provide an understanding of the philosophy of experimentation and the steps involved in experiment design and validation.

Learning Outcomes

The students are expected to have the ability to:

2. Design experiments, validate and test models.

Contents

*Philosophy of Experimentation:*The Philosophy of Science Governs the Practice of Science, Defining Scientific Research, Why Do Science? What Is Science For? The Need for Inductive Reasoning, The First Step: Establishing Your Framework, A Short History of Philosophy Relevant to Scientific Method, the Problem of Induction, Examining the Hypothesis-Falsification Framework, Hypothesis as a Framework for Scientific Projects, Scientific Settings in Which a Hypothesis-Falsification Framework Is Not Feasible, The Question and the Model: Forming an Inductive Framework for Scientific Projects (9 Lectures)

*System Validation:*The System, System Validation, Choice of a Model Organism or Technique:

Validation Experiments, System Validation Requirements for Distinct Experimental Readouts,

System Specificity: Specificity of Detection and Specificity of Perturbation, System Sensitivity:

Minimizing Signal to Noise to Improve Sensitivity of Detection, System Stability, Determining

Conditions to Measure Efficacy, System Validation: Determining Conditions to Measure Safety

(9 Lectures)

*The Experiment*Definition of the Experiment: The Framework for an Individual Experiment, The Negative Control: Distinct Types, The Requirement for the Positive Control, Method and Reagent Controls, Subject Controls, Assumption Controls, Experimentalist Controls: Establishing a Claim to an Objective Perspective, Biological Replicates, Technical Replicates, Experimental Repeats, Time Courses, and Dose Responses, Summary of Components of Individual Experiment (9 Lectures)

The ModelBuilding: the Model: Representations of the Experimental Data, Data Filtration,

Model induction: Asking Follow-Up Questions and Finishing the Project by Writing the

Manuscript, A Short Synopsis. (5 Lectures)

*Designing the Experimental Project***:** A Biological Example (10 Lectures)

Textbook

*1.*Glass D.J., *Experimental Design for Biologists,* 2nd Edition, Novartis Institutes for Biomedical Research, Cambridge, Massachusetts

*2.*Barker K., *At the Bench: A Laboratory Navigator,* Updated Edition, The Institute for Systems Biology, Seattle

Reference Books

1. Adams D. S., *Lab Math: A Handbook of Measurements, Calculations, and Other Quantitative Skills for Use at the Bench,* 2nd edition, The Tufts Center for Regenerative and Developmental Biology and Department of Biology, Tufts University

Online Course Material

1. Biology course, https://courses.ibiology.org/courses/course-v1:iBiology

Title	**Disease, Processes, Diagnostics & Therapeutics**	Number	BBL7XX0
Department	Bioscience and BioEngineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech	Type	Compulsory
Prerequisite	Nil		

Objectives

The Instructor will:

1. Introduction to fundamentals of immunology, clinical immunology, Diagnostics and therapeutics

Learning Outcomes

The students are expected to have the ability to:

1. Ability to understand immunological processes and 51nalyse diagnostics

Contents

*Immunology – Fundamental Concepts and Anatomy of Immune System:*Components of innate and acquired immunity; Complement and Inflammatory responses; Organs and cells of the immune system- primary and secondary lymphoid organs; Lymphatic system; MHC, Immune Responses Generated by B and T Lymphocytes, Immunoglobulins-basic structure, classes and subclasses, antigenic determinants; Organization of immunoglobulin genes; VDJ Recombination, Principles of cell 51nalyse51ry; Immunological basis of self –non-self discrimination; Kinetics and memory; B and T cell maturation, activation and differentiation into Subsets, Antigen-Antibody Interactions, Precipitation, agglutination and complement mediated immune reactions; Advanced immunological techniques – RIA, ELISA, Western blotting, ELISPOT assay, immunofluorescence, flow cytometry; Biosensor assay (13Lectures)

Clinical Immunology: Immunity to Infection : Bacteria, viral, fungal and parasitic infections (with examples from each group); Hypersensitivity – Type I-IV; Autoimmunity; Types of autoimmune diseases; Mechanism and role of CD4+ T cells; MHC and TCR in autoimmunity; Treatment of autoimmune diseases; Transplantation – Immunological basis of graft rejection; Clinical transplantation and immunosuppressive therapy *Tumor immunology :*Tumor antigens; Immune response to tumors and tumor evasion of the immune system, Cancer Immunotherapy, Immunodeficiency-Primary immunodeficiencies, Acquired or secondary immunodeficiencies, case studies (16 Lectures)

Vaccines and Drug Therapy(13 Lectures) Active and passive immunization; Live, killed, attenuated, sub unit vaccines; Vaccine technology- Role and properties of adjuvants, recombinant DNA and protein based vaccines, plant-based vaccines, reverse vaccinology; Peptide vaccines, conjugate vaccines; Antibody genes and antibody engineering- chimeric and hybrid monoclonal antibodies; Catalytic antibodies and generation of immunoglobulin gene libraries (13 Lectures)

Textbook

1. Janeway,C (1996), *Immunobiology*, 4th EditionGarland Publishing

Reference Books

2. R,A, Goldsby., Thomas, J.K., and Barbara, A, Osborne. (2002), *Kuby Immunology*, 6th Edition Freeman

Self-learning Material

1. Manjunath R., Nandi D, Karande A, *Essentials in Immunology,* Indian Institute of Science Bangalore, http://nptel.ac.in/courses/104108055/, NPTEL Course Material.

2. Kumar S, *Cellular and Molecular Immunology,* Indian Institute of Technology Guwahati, http://nptel.ac.in/courses/102103038/,NPTEL Course Material.

Title	**Cardiovascular Physiology: Signals, systems and controls**	Number	BBLXX0
Department	Bioscience and BioEngineering	L-T-P [C]	1–0–0
Offered for	M.Tech	Type	Elective
Prerequisite	Nil		

Objectives

The Instructor will:

1. Provide an understanding of the hierarchical organization of Chemical and electrical signals and Control Mechanisms including Feed-back loops and switches for controlling Energy, Mechanics, Flow and Transport.

2. Provide an understanding of the workings of the human body in context of engineering principles so as to develop an interdisciplinary outlook to biological as well as engineering problem-solving.

Learning Outcomes

The students are expected to have the ability to:

1.Understand basic human physiology

2.Analyze physiological systems from an engineering perspective

3.Imagine engineering solutions that can solve biological problems OR can get inspired by biology to solve engineering problems.

Contents

*CardiopulmonaryPhysiology (*14lectures*)*: Electricity in cardiac cells, Control of cardiac Automaticity, ECG, Cardiac and smooth muscle, Cardiovascular mechanics, and dynamics, Microcirculation control mechanisms, Cerebral and Pulmonary circulation: controls and switches, congestive heart failure, Shock, Breathing: forces, volume and flow, Resistance to Air flow, Alveolar gas exchange and transport, Acid-base balance, Neural control of Respiration.

Textbook

1. Joseph Feher., (2016), *Quantitative Human Physiology,* 2nd Edition, Academic Press

2. E.N. Marieb (2006), *Human Anatomy and Physiology*, 6th Edition, Pearson Education

Reference Books

1. Boron W. F, Boulpaep E. L. *Medical Physiology*, 3rd Edition, Elsevier.

Online Course Material

1. Dennis Freeman, 6-021j *Quantitative Physiology: Cells and Tissues*, Fall 2004, MIT OpenCourseWare Massachusetts Institute of Technology, https://ocw.mit.edu. License: Creative Commons BY-NC-SA

2.Venegas, J, Mark, F. *Quantitative Physiology: Organ Transport Systems,* MIT OpenCourseWare Massachusetts Institute of Technology, https://ocw.mit.edu. License: Creative Commons BY-NC-SA

Title	**Human Physiology Laboratory**	Number	BBXXX
Department	Bioscience and BioEngineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech	Type	Compulsory
Prerequisite	Nil		

Objectives

The Instructor will:

1. Provide an understanding of the hierarchical organization of Chemical and electrical signals and Control Mechanisms including Feed-back loops and switches for controlling Energy, Mechanics, Flow and Transport.
2. Provide an understanding of the workings of the human body in context of engineering principles so as to develop an interdisciplinary outlook to biological as well as engineering problem-solving.

Learning Outcomes

The students are expected to have the ability to:

1.Understand basic human physiology

2.Analyze physiological systems from an engineering perspective

3.Imagine engineering solutions that can solve biological problems OR can get inspired by biology to solve engineering problems.

Contents

Physiology of excitable Cells: Resting Membrane Potential, Modeling action potentials and 54nalyse54ry Conduction, Neuromuscular transmission, Introduction to Neurons in Action

CardiopulmonaryPhysiology: bike ergometer with heart rate interface, peak flow meter and respiratory volumes, Muscle Function assessment (electromyography), health and fitness assessment using balance and mobility parameters.

Stress and Exercise Physiology

eye tracking, electro electroencephalography (EEG), verbal response (TA) and systematic observation using dedicated software (Morae) to measure cognitive load; use pupil dilation, galvanic skin response (GSR)

Textbook

1. Joseph Feher., (2016), *Quantitative Human Physiology,* 2nd Edition, Academic Press
2. E.N. Marieb (2006), *Human Anatomy and Physiology*, 6th Edition, Pearson Education

Reference Books

1. Boron W. F, Boulpaep E. L. *Medical Physiology*, 3rd Edition, Elsevier.

Online Course Material

1. Moore JW, Stuart A.E, *Neurons in Action 2: Tutorials and Simulations in NEURON,* Yale J Biol Med. 2008 Mar; 81(1): 50–51.

Title	**Cellular and Molecular Neuroscience**	Number	BBXXX
Department	Bioscience and Bioengineering	L-T-P [C]	3–0–2 [4]
Offered for	B.Tech	Type	Elective
Prerequisite	Nil		

Objectives

The Instructor will:

1. Provide introduction to the basic principles to understand how the brain works

2. Provide an understanding of the structure and function of the Human brain in health and disease

Learning Outcomes

The students are expected to have the ability to:

1. Integrate their understanding of structural and functional units of the human brain for design of health technologies

Contents

Introduction of Neuroscience [10 lectures]:Nervous systems, basic structure, development and complexity; senses and responses as essential components of life, *Cellular units of the brain* Neurons; types, structure and function, Glia, Maintenance of cellular homeostasis in the brain, the blood-brain barrier.

Inter and Intracellular 56nalyse56ry[10 lectures]*:* Resting membrane potential, action potential and impulse propagation, importance of ion channels, microtubules organization, myelin sheath; secondary messengers, Neurotransmitters, classes, criteria for classification,the synapse, synaptic transmission, electrical and chemical synapses, synaptic integration of information, Neuromuscular junction, primary and secondary motor cortex, integration of sensory signals to motor actions, motor neuron diseases

Sensory perception in health and disease [10 lectures]*:* sensory receptors; properties, sensitization and desensitization, sensory coding, Somatosensory System; organization, receptors (mechanoreceptors, proprioceptors, nociceptors, thermal receptors and Visceral sensations), Auditory sensory perception; structure of the internal ear, modulation of sound waves into nerve signal, integration within the auditory cortex, Visual pathways; organization, visual perception and processing, photoreceptors, processing and integration of visual information.

Laboratory Experiments [12 laboratory sessions]

Immunohistochemistry of the human brain, understanding distinct cellular populations and morphologies, Neuronal cell culture; neurons, microglia, astrocytes and endothelial cells, assessment of morphological changes with stress and disease, visualization of inter and intracellular cell 56nalyse56ry; cell migration, proliferation, secreted cytokines and chemokines.

Textbook

1. Kandel,E., (2012), *Principles of Neural Science*, 5th Edition, Elsevier

2. Zigmond M (2012), *Fundamental Neuroscience*, 4th Edition Elsevier

Reference Books

1. Lodish B, Kaiser K (2016), *Molecular Cell Biology*, 8th Edition, WH Freeman

Online Course Material

1. Constantine-Paton M, *9.013J / 7.68J Cell and Molecular Neurobiology*, Spring 2008, MIT OpenCourseWare Massachusetts Institute of Technology, https://ocw.mit.edu. License: Creative Commons BY-NC-SA

Title	**Sensory Neural Systems**	Number	BBXXX
Department	Bioscience and Bioengineering	L-T-P [C]	3–0–0 [3]
Offered for	B.Tech	Type	Elective
Prerequisite	Nil		

Objectives

The Instructor will:

1. Provide introduction to the basic principles to understand how the sensory neural pathways work
2. Provide an understanding of the structure and function of the sensory neural pathways in health and disease

Learning Outcomes

The students are expected to have the ability to:

1. Integrate their understanding of structural and functional units of the human brain for design of health technologies

Contents

BL6XX1 Synaptic communication: function and dysfunction [1-0-0] [14 lectures]*:* sensory receptors; properties, sensitization and desensitization, sensory coding, Somatosensory System; organization, receptors (mechanoreceptors, proprioceptors, nociceptors, thermal receptors and Visceral sensations), Disorders of sensory perception. (1 fractal)

BBL6XX2 Auditory perception: from cell to signal [1-0-0] [14lectures]: Auditory sensory perception; structure of the internal ear, modulation of sound waves into nerve signal, integration within the auditory cortex, (1fractal)

BBL6XX1 Visual perception [1-0-0] [14lectures] Visual pathways; organization, visual perception and processing, photoreceptors, processing and integration of visual information. Disorders of visual perception (1fractal)

Textbook

1. Kandel,E., (2012), *Principles of Neural Science*, 5th Edition, Elsevier
2. Zigmond M (2012), *Fundamental Neuroscience*, 4th Edition Elsevier

Reference Boo

1. Lodish B, Kaiser K (2016), *Molecular Cell Biology*, 8th Edition, WH Freeman

Online Course Material

1. Constantine-Paton M, *9.013J / 7.68J Cell and Molecular Neurobiology*, Spring 2008, MIT OpenCourseWare Massachusetts Institute of Technology, https://ocw.mit.edu. License: Creative Commons BY-NC-SA

Title	**Human Physiology Laboratory**	Number	BBXXX
Department	Bioscience and BioEngineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech	Type	Compulsory
Prerequisite	Nil		

Objectives

The Instructor will:

1. Provide an understanding of the hierarchical organization of Chemical and electrical signals and Control Mechanisms including Feed-back loops and switches for controlling Energy, Mechanics, Flow and Transport.

2. Provide an understanding of the workings of the human body in context of engineering principles so as to develop an interdisciplinary outlook to biological as well as engineering problem-solving.

Learning Outcomes

The students are expected to have the ability to:

1.Understand basic human physiology

2.Analyze physiological systems from an engineering perspective

3.Imagine engineering solutions that can solve biological problems OR can get inspired by biology to solve engineering problems.

Contents

Physiology of excitable Cells: Resting Membrane Potential, Modeling action potentials and 60nalyse60ry Conduction, Neuromuscular transmission, Introduction to Neurons in Action

CardiopulmonaryPhysiology: bike ergometer with heart rate interface, peak flow meter and respiratory volumes, Muscle Function assessment (electromyography), health and fitness assessment using balance and mobility parameters.

Stress and Exercise Physiology

eye tracking, electro electroencephalography (EEG), verbal response (TA) and systematic observation using dedicated software (Morae) to measure cognitive load; use pupil dilation, galvanic skin response (GSR)

Textbook

1. Joseph Feher., (2016), *Quantitative Human Physiology,* 2nd Edition, Academic Press

2. E.N. Marieb (2006), *Human Anatomy and Physiology*, 6th Edition, Pearson Education

Reference Books

1. Boron W. F, Boulpaep E. L. *Medical Physiology*, 3rd Edition, Elsevier.

Online Course Material

1. Moore JW, Stuart A.E, *Neurons in Action 2: Tutorials and Simulations in NEURON,* Yale J Biol Med. 2008 Mar; 81(1): 50–51.

Title	**Quantitative Physiology: systems and controls of**	Number	BBXXX

	the human machine		
Department	Bioscience and BioEngineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech	Type	Compulsory
Prerequisite	Nil		

Objectives

The Instructor will:

1. Provide an understanding of the hierarchical organization of Chemical and electrical signals and Control Mechanisms including Feed-back loops and switches for controlling Energy, Mechanics, Flow and Transport.

2. Provide an understanding of the workings of the human body in context of engineering principles so as to develop an interdisciplinary outlook to biological as well as engineering problem-solving.

Learning Outcomes

The students are expected to have the ability to:

1.Understand basic human physiology

2.Analyze physiological systems from an engineering perspective

3.Imagine engineering solutions that can solve biological problems OR can get inspired by biology to solve engineering problems.

Contents

Physical and Chemical Foundations of Physiology: Homeostasis, energy balance, feedback control systems, pressure driven flow, Electrical Force, Potential, Capacitance, and Current, Electrochemical Potential and Free Energy, Membrane transport across a biological membrane.

Physiology of excitable Cells: The Origin of the Resting Membrane Potential, GHK equation, action potentials, Membrane excitability, Modeling action potentials, 61nalyse61ry Conduction, Skeletal Muscle Mechanics, Neuromuscular transmission, Excitation–Contraction Coupling Motor units, Size Principle, Concentric, Isometric, and Eccentric Contractions, Fatigue and Tetanus.

CardiopulmonaryPhysiology: Electricity in cardiac cells, Control of cardiac Automaticity, ECG, Cardiac and smooth muscle, Cardiovascular mechanics, and dynamics, Microcirculation control mechanisms, Cerebral and Pulmonary circulation: controls and switches, congestive heart failure, Shock, Breathing: forces, volume and flow, Resistance to Air flow, Alveolar gas exchange and transport, Acid-base balance, Neural control of Respiration.

Renal Physiology: Body fluid compartments and overview of renal function, Measurements of function and clearance, Glomerular filtration/Renal Hemodynamics, Tubular transport of electrolytes and water, Concentration and dilution of urine, Regulation of sodium balance, extracellular volume and Blood pressure, Renal mechanisms of hypertension.

Textbook

1. Joseph Feher., (2016), *Quantitative Human Physiology,* 2nd Edition, Academic Press

2. E.N. Marieb (2006), *Human Anatomy and Physiology*, 6th Edition, Pearson Education

Reference Books

1. Boron W. F, Boulpaep E. L. *Medical Physiology*, 3rd Edition, Elsevier.

Online Course Material

1. Dennis Freeman, 6-021j *Quantitative Physiology: Cells and Tissues*, Fall 2004, MIT OpenCourseWare Massachusetts Institute of Technology, https://ocw.mit.edu. License: Creative Commons BY-NC-SA

2.Venegas, J, Mark, F. *Quantitative Physiology: Organ Transport Systems,* MIT OpenCourseWare Massachusetts Institute of Technology, https://ocw.mit.edu. License: Creative Commons BY-NC-SA

Title	**Immunodiagnostics and therapeutics**	Number	

Department	Bioscience & Bioengineering	L-T-P [C]	2–0–2 [3]
Offered for	M.Tech. (MT) Program	Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. Provide an introduction to fundamentals techniques of clinical immunology and Immune based Diagnostics

Learning Outcomes

The students are expected to have the ability to:

1. Immunology based diagnostics techniques for to create and 63nalyse diagnostics

Contents

Immunodiagnostics [14 lectures]: Selection of animals for immunological assays, Preparation of antigens, Immunization and methods of bleeding, Serum separation, Storage. Antibody titre by ELISA method. Double diffusion, Immuno-electrophoresis and Radial Immuno diffusion. Complement fixation test. Hybridoma technology and monoclonal antibody production. Lymphoproliferation by mitogen / antigen.

Immunotherapeutics[14 lectures]: Active and passive immunization; Live, killed, attenuated, sub unit vaccines; Vaccine technology- Role and properties of adjuvants, recombinant DNA and protein based vaccines, plant-based vaccines, reverse vaccinology; Peptide vaccines, conjugate vaccines; Antibody genes and antibody engineering- chimeric and hybrid monoclonal antibodies; Catalytic antibodies and generation of immunoglobulin gene libraries

Laboratory Experiments *[12 experiments]:*

Immunoblotting for specific antigens, Dot blot assay, Blood smear identification of leucocytes by Giemsa stain. Quantification of Phagocytic activity, Separation of mononuclear cells by Ficoll-Hypaque. Immunohistochemistry (direct and indirect peroxidase assay), detection of Salmonella genus which causes enteric or Typhoid Fever by using qualitative slide agglutination test (Widal test), Detection of Treponemes responsible for veneral diseases such as syphilis (VDRL) test, IgG Purification technique (Protein A Based, Spin Column)

Textbook

1. R.A. Goldsby., Thomas,J.K., and Barbara,A, Osborne., *Kuby Immunology*, Freeman,2002, 6th Edition

2. Stanier, R. Y., *General Microbiology*, W.H. Freeman and Co., 2009.

3. Pelczar, M.J., Chan, E. C. S., Krieg, N.R., *Microbiology*, Tata McGraw – Hill Education, 2001

Reference Books

1. Murphy, K., Travers, P., Walport, M., & Janeway, C. (2012). *Janeway's Immunobiology*. New York: Garland Science.

3. Madigan, M.T., Martinko, J.M., Brock, *Biology of Microorganisms*, Prentice-Hall, Inc., 2006, 11th Edition.

Online Course Material

1 NPTEL Video Lectures on Essentials in Immunology by Prof. R. Manjunath, Prof. Dipankar Nandi , Prof. Anjali Karande, Indian Institute of Science Bangalore (http://nptel.ac.in/courses/104108055/)

2. NPTEL Video Lectures on Cellular and Molecular Immunology by Prof. Sachin Kumar, Indian Institute of Technology Guwahati (http://nptel.ac.in/courses/102103038/)

Title	**Sensory Neural Systems**	Number	*BBL7XX0*
Department	Bioscience and Bioengineering	L-T-P [C]	3–0–0 [3]
Offered for	B.Tech	Type	Elective
Prerequisite	Nil		

Objectives

The Instructor will:

1. Provide introduction to the basic principles to understand how the sensory neural pathways work

2. Provide an understanding of the structure and function of the sensory neural pathways in health and disease

Learning Outcomes

The students are expected to have the ability to:

1. Integrate their understanding of structural and functional units of the human brain for design of health technologies

Contents

BBL7XX1 Synaptic communication: function and dysfunction [1-0-0] [14 lectures]*:* sensory receptors; properties, sensitization and desensitization, sensory coding, Somatosensory System; organization, receptors (mechanoreceptors, proprioceptors, nociceptors, thermal receptors and Visceral sensations), Disorders of sensory perception. (1 fractal)

BBL7XX2 Auditory perception: from cell to signal [1-0-0] [14lectures]: Auditory sensory perception; structure of the internal ear, modulation of sound waves into nerve signal, integration within the auditory cortex, (1fractal)

BBL7XX1 Visual perception [1-0-0] [14lectures] Visual pathways; organization, visual perception and processing, photoreceptors, processing and integration of visual information. Disorders of visual perception (1fractal)

Textbook

1. Kandel,E., (2012), *Principles of Neural Science*, 5th Edition, Elsevier

2. Zigmond M (2012), *Fundamental Neuroscience*, 4th Edition Elsevier

Reference Books

1. Lodish B, Kaiser K (2016), *Molecular Cell Biology*, 8th Edition, WH Freeman

Online Course Material

1. Constantine-Paton M, *9.013J / 7.68J Cell and Molecular Neurobiology*, Spring 2008, MIT OpenCourseWare Massachusetts Institute of Technology, https://ocw.mit.edu. License: Creative Commons BY-NC-SA

Title	**Synaptic communication: function and dysfunction**	Number	BBL6XX3
Department	Bioscience and Bioengineering	L-T-P [C]	1–0–0 [1]
Offered for	B.Tech	Type	Elective
Prerequisite	Nil		

Objectives

The Instructor will:

1. Provide introduction to the basic principles to understand how synaptic communication works

2. Provide an understanding of Synaptic function in health and disease

Learning Outcomes

The students are expected to have the ability to:

1. Integrate their understanding of structural and functional units of the human brain for design of health technologies

Contents

Synpatic structure: function and dysfunction (1 fractal) Resting membrane potential, action potential and impulse propagation, importance of ion channels, secondary messengers, Neurotransmitters, classes, criteria for classification,the synapse, synaptic transmission, electrical and chemical synapses, synaptic integration of information, Neuromuscular junction, primary and secondary motor cortex, integration of sensory signals to motor actions, motor neuron diseases [14lectures].

Textbook

1. Kandel,E., (2012), *Principles of Neural Science*, 5th Edition, Elsevier

2. Zigmond M (2012), *Fundamental Neuroscience*, 4th Edition Elsevier

Reference Books

1. Lodish B, Kaiser K (2016), *Molecular Cell Biology*, 8th Edition, WH Freeman

Online Course Material

1. Constantine-Paton M, *9.013J / 7.68J Cell and Molecular Neurobiology*, Spring 2008, MIT OpenCourseWare Massachusetts Institute of Technology, https://ocw.mit.edu. License: Creative Commons BY-NC-SA

Title	**Cell and Molecular Biology**	Number	BBL7XX0
Department	Bioscience & Bioengineering	L-T-P [D]	3–0–0 [3]
Offered for	M.Tech. 1st Year	Type	Elective
Prerequisite	Nil		

Objectives

The Instructor will:

1. offer both basic as well as advanced knowledge of cell biology and molecular biology, mechanisms and progress fundamental conceptual base for scientific research understanding

Learning Outcomes

The students will have an ability to

1. Fundamental comprehensive knowledge of cellular and molecular biology mechanisms and their regulation to understand advances and implications in health associated biotechnology

Contents

Introduction to Cell and Molecular Biology: Structure and functions of cell-organelles; Cell membrane physiochemical properties; Molecular Organization, biogenesis and functions of cell membrane; Eukaryotic chromosomes (Lectures-10)

Cell Reproduction: Introduction to cell division; Biological principles of Mitosis and Meiosis; Difference and comparison of cell division among prokaryotic and eukaryotic organisms; Cytokines; Regulation of cell division; Cancer and cell cycle deregulation (Lectures-12)

Cell Death and Diseases: Apoptosis: Phases and significance, Morphological and Biochemical changes associated With apoptotic cells, Apoptotic Pathways and regulators; Molecular genetics and diseases associated with cell death (Lectures-10)

Mechanisms of Molecular Biology: Prokaryotic & Eukaryotic Transcription; Transcription unit; Transcript processing; Processing of RNA Eukaryotic transcription; RNA polymerase; Eukaryotic promoters and enhancers (Lectures-10)

Textbook

1. Bruce Alberts, (2014), *Molecular Biology of the cell,* 6th Edition, Garland Science

2. Lodish., and W.H Freeman, (2016), *Molecular Cell Biology,* 8th Edition, Macmillan learning

3. Gerald Karp and Nancy L Pruitt, (2016), *Cell and Molecular Biology*, John 8th Edition Wiley and Sons

Self-Learning Material

1. D. Karunagaran, *Molecular Cell Biology*, Department of Biotechnology Indian Institute of Technology Madras, https://nptel.ac.in/syllabus/102106025/

Preparatory Course Material

1. NPTEL Lectures: on *Molecular Cell Biology*, Indian Institute of Technology Madras, http://nptel.ac.in/syllabus/102106025/

Title	**Immunodiagnostics and therapeutics**	Number	BBL7XX0
Department	Bioscience & Bioengineering	L-T-P [C]	2–0–2 [3]
Offered for	M.Tech. (MT) Program	Type	Elective

Objectives

The Instructor will:

1. Provide an introduction to fundamentals techniques of clinical immunology and Immune based Diagnostics

Learning Outcomes

The students are expected to have the ability to:

1. Immunology based diagnostics techniques for to create and 68nalyse diagnostics

Contents

Immunodiagnostics [14 lectures]: Selection of animals for immunological assays, Preparation of antigens, Immunization and methods of bleeding, Serum separation, Storage. Antibody titre by ELISA method. Double diffusion, Immuno-electrophoresis and Radial Immuno diffusion. Complement fixation test. Hybridoma technology and monoclonal antibody production. Lymphoproliferation by mitogen / antigen.

Immunotherapeutics[14 lectures]: Active and passive immunization; Live, killed, attenuated, sub unit vaccines; Vaccine technology- Role and properties of adjuvants, recombinant DNA and protein based vaccines, plant-based vaccines, reverse vaccinology; Peptide vaccines, conjugate vaccines; Antibody genes and antibody engineering- chimeric and hybrid monoclonal antibodies; Catalytic antibodies and generation of immunoglobulin gene libraries

Laboratory Experiments *[12 experiments]:*

Immunoblotting for specific antigens, Dot blot assay, Blood smear identification of leucocytes by Giemsa stain. Quantification of Phagocytic activity, Separation of mononuclear cells by Ficoll-Hypaque. Immunohistochemistry (direct and indirect peroxidase assay), detection of Salmonella genus which causes enteric or Typhoid Fever by using qualitative slide agglutination test (Widal test), Detection of Treponemes responsible for veneral diseases such as syphilis (VDRL) test, IgG Purification technique (Protein A Based, Spin Column)

Textbook

1. R.A. Goldsby., Thomas,J.K., and Barbara,A, Osborne., *Kuby Immunology*, Freeman,2002, 6th Edition

2. Stanier, R. Y., *General Microbiology*, W.H. Freeman and Co., 2009.

3. Pelczar, M.J., Chan, E. C. S., Krieg, N.R., *Microbiology*, Tata McGraw – Hill Education,

2001

Reference Books

1. Murphy, K., Travers, P., Walport, M., & Janeway, C. (2012). *Janeway's Immunobiology*. New York: Garland Science.

2. Madigan, M.T., Martinko, J.M., Brock, *Biology of Microorganisms*, Prentice-Hall, Inc., 2006, 11th Edition.

Online Course Material

1. NPTEL Video Lectures on Essentials in Immunology by Prof. R. Manjunath, Prof. Dipankar Nandi , Prof. Anjali Karande, Indian Institute of Science Bangalore (http://nptel.ac.in/courses/104108055/)

2. NPTEL Video Lectures on Cellular and Molecular Immunology by Prof. Sachin Kumar, Indian Institute of Technology Guwahati (http://nptel.ac.in/courses/102103038/)

Title	**Synaptic communication: function and dysfunction**	Number	BBL6XX3
Department	Bioscience and Bioengineering	L-T-P [C]	1–0–0 [1]
Offered for	B.Tech	Type	Elective
Prerequisite	Nil		

Objectives

The Instructor will:

1. Provide introduction to the basic principles to understand how synaptic communication works
2. Provide an understanding of Synaptic function in health and disease

Learning Outcomes

The students are expected to have the ability to:

1. Integrate their understanding of structural and functional units of the human brain for design of health technologies

Contents

Synpatic structure: function and dysfunction (1 fractal) Resting membrane potential, action potential and impulse propagation, importance of ion channels, secondary messengers, Neurotransmitters, classes, criteria for classification, the synapse, synaptic transmission, electrical and chemical synapses, synaptic integration of information, Neuromuscular junction, primary and secondary motor cortex, integration of sensory signals to motor actions, motor neuron diseases [14lectures].

Textbook

1. Kandel,E., (2012), *Principles of Neural Science*, 5th Edition, Elsevier
2. Zigmond M (2012), *Fundamental Neuroscience*, 4th Edition Elsevier

Reference Books

1. Lodish B, Kaiser K (2016), *Molecular Cell Biology*, 8th Edition, WH Freeman

Online Course Material

1. Constantine-Paton M, *9.013J / 7.68J Cell and Molecular Neurobiology*, Spring 2008, MIT OpenCourseWare Massachusetts Institute of Technology, https://ocw.mit.edu. License: Creative Commons BY-NC-SA

Title	**Microbes as sensors**	Number	BBL7XX0
Department	Bioscience and Bioengineering	L-T-P [C]	1-0-0 [1]
Offered for		Type	Compulsory
Prerequisite			

Objectives

1. The instructor will discuss the methods by which living microbes can be used as sensors.

Learning Outcomes

1. Students will have an ability to design live microbial based biosensors for sensing specific pollutants, marker for environment and/or health monitoring

Contents

Introduction: Advantages of using microbes as sensors, physical and chemical methods of microbial, immobilization. (4 lectures)

Electrochemical microbial biosensor: Amperometric, potentiometric and conductimetric (5 lectures)

Optical biosensors; bioluminescence, fluorescence, and calorimetric based sensors (2 lectures).

Metabolism based: Microbial sensors based on analysis of oxygen reduction rate or carbon di oxide production rate. (3 lectures)

Textbook

No textbook. The research papers will serve as the reading material and reference material

Reference Books

1. Brock, et al., (2012), Biology of Microorganisms, 13th edition Ben,jamin Cummings, Boston, MA.

Online course material

None

Title	**Measurements in Remote Healthcare**	Number	CSL7XX0
Department	Computer Science & Enginering	L-T-P [C]	1-0-0 [1]
Offered for		Type	Elective
Prerequisite			

Objectives

The instructor will:

1. Discuss techniques to design the sensor-based system for remote healthcare

2. Provide mechanisms to design and develop mobile platforms for healthcare sensors & data

Learning Outcomes

The students will have an ability to:

1. design end-to-end wireless sensors based system in remote areas

2. critically identify and use the tools for sensor placement, and data processing

Contents

Contents

Sensor, Networks & Data for Healthcare: Overview of wireless sensor networks, Network characteristics, Network Design and Challenges, Wireless Sensor Network Protocol Stack, Sensor Data aggregation techniques, Sensor Data storage, Data Management and Processing; Time Synchronisation in WSN: Need and Techniques; Sensor Node localisation: Need and Techniques; Security and Privacy - Authentication and Cryptography; Wireless Sensor and Actuator Networks - Bidirectional Network design (10 lectures)

Healthcare on Mobile Platforms: Need for mobile platforms for healthcare applications, Mobile application development for Healthcare: Wireless Sensor Data collection (Bluetooth, WiFi, 3G, 4G), Data Processing and Alert generation; (4 lectures)

Textbook

1. Jun Zheng, Abbas Jamalipour, (2009), Wireless Sensor Networks: A Networking Perspective, A John Wiley & Sons, IEEE Publication

2. Nawaz Mohamudally, (2017), Smartphones from an Applied Research Perspective, InTech

Reference Books

1. Koushik Maharatna, Silvio Bonfiglio, (2014), Systems Design for Remote Healthcare, Springer

Online course material

Course Title	**Analog and Interfacing Circuits**	Number	**EEL7XX0**
Department	Electrical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M. Tech. 1st year	Type	Compulsory
Pre-requisite	Digital and Analog Electronics		

Objectives

The Instructor will:

1. Familiarize students with the concepts of Analog IC Design and give them a comprehensive overview of various amplifiers.
2. Familiarize the students with different building blocks of a mixed signal interface circuit design essential for sensors and IoT.

Learning Outcomes

Students are expected to have the ability to:

1. Understand fundamental principles of CMOS Analog IC Design and interfacing of analog signals with the digital signal processing circuits.
2. Apply the circuit design fundamentals for IoT applications.
3. Work on design tools like Cadence/Mentor Graphics

Contents

EEL7XX1: Fundamentals of Analog Circuits and Design [1-0-0]

(Fractal 1)Introduction toAnalog VLSI and design issues in CMOS technologies, MOS models, SPICE Models, Single stage amplifiers, Biasing circuits, Voltage and Current reference circuits, Feedback analysis, Multistage amplifiers, Mismatch and noise analysis, Differential amplifiers, Oscillators (14 Lectures)

EEL7XX2: Readout Electronics [1-0-0]

(Fractal 2)*Switch capacitor circuits:* Principles and applications in filter design; switches and related design issues, variable gain amplifier, low noise and high speed amplifier topologies. *Analog to digital converters:*Types of ADCs, static and dynamic characteristics; track and hold, and sample and hold circuits; comparators; detail design analysis for successive approximation register (SAR) ADCs, discrete-time and continuous time sigma-delta ADCs(14 Lectures)

EEL7XX3: Digital to Analog Converters Design [1-0-0]

(Fractal 3)*Digital to Analog Converters:*Voltage-based DACs; charge-based DACs; current-based DACs – binary and thermometer currents. *Phase-locked loop*: Basics; PLL dynamics; voltage controlled oscillator, frequency synthesis. Applications: Wearable Biomedical IoT nodes (14 Lectures)

Text Books

1. Razavi, B., (2016), *Design of Analog CMOS Integrated Circuits*, 2nd Edition, McGraw-Hill Education.
2. R. Jacob Baker, H.W.Li, and D.E. Boyce, (2009), – *CMOS Circuit Design ,Layout and Simulation*, 2nd Edition, Prentice-Hall of India

3. David A. Johns, Ken Martin, (2013), “Analog Integrated Circuit Design”, 2nd Edition, John Wiley and Sons.

Self Learning material

1. Shanthi Pavan, VLSI Data Conversion Circuits, NPTEL Course Material, Department of Electrical Engineering, Indian Institute of Technology Madras, https://nptel.ac.in/courses/117106034/
2. Nagendra Krishnapura, Analog Integrated Circuit Design, Department of Electrical Engineering, Indian Institute of Technology Madras, https://nptel.ac.in/courses/117106030/

Preparatory Course Material

1. P. E. Allen, D. R. Holberg (2013), *CMOS Analog Circuit Design*, 3rd Edition, Oxford University Press.
2. R. Gregorian, G. C. Temes, (2008), “*Analog MOS Integrated Circuits for Signal Processing*”, John Wiley and Sons.

Program Elective Set 4

Systems Biology

Title	**Immunotechnology**	Number	BBL7XX0
Department	Bioscience and Bioengineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech	Type	Elective
Prerequisite	Nil		

Objectives

The Instructor will:Introduction to fundamentals of immunology, clinical immunology, Diagnostics and therapeutics

Learning Outcomes

The students are expected to have the ability to: understand immunological processes and analyze diagnostics

Contents

BBL7XX1: Fundamental Concepts:* Antigen-Antibody Interactions *[1-0-0]

*(Fractal 1)*Precipitation, agglutination and complement mediated immune reactions; Advanced immunological techniques - RIA, ELISA, Western blotting, ELISPOT assay, immunofluorescence, flow cytometry; Biosensor assay *(14 Lectures)*

BBL7XX2: Clinical Immunology [1-0-0]

(Fractal 1) Clinical transplantation and immunosuppressive therapy; Tumor antigens; Immune response to tumors and tumor evasion of the immune system, Cancer Immunotherapy, Immunodeficiency-Primary immunodeficiencies, Acquired or secondary immunodeficiencies, case studies *(14 Lectures)*

BBL7XX3: Vaccines and Drug Therapy [1-0-0]

(Fractal 3) Active and passive immunization; Live, killed, attenuated, sub unit vaccines; Vaccine technology- Role and properties of adjuvants, recombinant DNA and protein based vaccines, plant-based vaccines, reverse vaccinology; Peptide vaccines, conjugate vaccines; Antibody genes and antibody engineering- chimeric and hybrid monoclonal antibodies; Catalytic antibodies and generation of immunoglobulin gene libraries *(14 Lectures)*

Textbook

1. Janeway,C (1996), *Immunobiology*, 4th EditionGarland Publishing

Reference Books

1. R,A, Goldsby., Thomas,J.K., and Barbara,A, Osborne. (2002), *Kuby Immunology*, 6th Edition Freeman

Online Course Material

1. Manjunath R., Nandi D, Karande A, *Essentials in Immunology,* Indian Institute of Science Bangalore, http://nptel.ac.in/courses/104108055/, NPTEL Course Material.

2. Kumar S, *Cellular and Molecular Immunology,* Indian Institute of Technology Guwahati, http://nptel.ac.in/courses/102103038/, NPTEL Course Material.

Title	**Thermodynamics and Chemical Kinetics**	Number	CYL6XX1 CYL6XX3
Department	Chemistry	L-T-P [C]	2–0–0 [2]
Offered for		Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. Provide the connection between microscopic theory and thermodynamics.
2. Describe how complex phenomena can be transferred into simple models.

Learning Outcomes

The students will have an ability to:

1. Predict properties of many-body systems starting from its microscopic constituents and their interactions
2. Connect microscopic theory to chemical reaction

Contents

CYL6XX1: Thermodynamics [1-0-0]

thermodynamics laws, state and path functions and their applications; thermodynamic description of various types of processes; Maxwell's relations; spontaneity and equilibria

Temperature and pressure dependence of thermodynamic quantities; Le Chatelier's principle (14 lectures)

CYL6XX3: Chemical Kinetics [1-0-0]

Empirical rate laws and temperature dependence; complex reactions; steady state approximation, determination of reaction mechanisms

Mechanism: Theory of reaction rates, activation energy, transition state theory, potential energy surface, uni-molecular reaction rate, enzyme kinetics, salt effects (14 lectures).

Text Books

1. D. McQuarrie and J. D. Simon, (2014) Molecular Thermodynamics, Viva Books.

2. D. McQuarrie, (2011) Physical Chemistry, A Molecular Approach, Viva Books.

Self Learning Material

K. J. Laidler, (2013) Chemical Kinetics, Pearson.

Self Learning Material

1. V.Balakrishnan, Department of Physics, IIT Madras. http://nptel.iitm.ac.in

2. De, A. K. Advanced Chemical Thermodynamics and Kinetics, NPTEL Course Material, Chemical Sciences, IISER Mohali, https://onlinecourses.nptel.ac.in/noc18_cy20/

Title	**Synthetic Biology**	Number	BB7XX0
Department	Bioscience and Bioengineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech	Type	Elective
Prerequisite	Nil		

Objectives

The Instructor will:

1. Teach the workings of DNA, RNA and proteins at their level of structure, regulatory elements and networks as building blocks or “biobricks” that can then be assembled into novel “devices” and “systems”.

2. enable students to create simple circuits from biological components.

3. Enable hands-on design and understanding of modularity and construction via Laboratory exercises using computer software enabling coding DNA sequences and simulating genetic engineering experiments

Learning Outcomes

The students are expected to have the ability to:

1. Analyze biological systems from an engineering perspective

2.Imagine engineering solutions that can solve biological problems OR get inspired by biology to solve engineering problems.

Contents

Introduction to Synthetic Biology: Introduction to DNA, RNA, proteins and standard functional components of a cell, Basics of coding with DNA: Registry of standard biological parts, Analytical Tools: Genomics, Proteomics, Metabolomics (7 lectures)

*Simulation Tools:*Gene designer, Serial Cloner, Vector NTI, Lab sessions in computer center (7 lectures)

*Experimental Tools: P*CR: Basics of PCR, Primer design, Error detection and correction. Gel electrophoresis: gel extraction ligation and transformation, Biobrick discovery and creation technique: mining nature for parts, Creating new parts with PCR, Cloning: basics, Cloning a new part into a “BioBrick” vector, Sequencing. (14 lectures)

Quality control: Quality control Screens, Standardized Measurements for BioBricks, Assembly and measurement of a BioBrick system (7 lectures)

Designing with Synthetic Biology: iGEM questions: What do you want Biology to do for you? Student presentations (7 lectures)

Textbook

*1.*Freemont, S. P , Kitney, R.I, *Synthetic Biology-a primer*, *1st Edition*

Reference Books

1. Church GM, Regis E*, Regenesis: How Synthetic Biology Will Reinvent Nature and Ourselves.*

Self-learning Material

http://synbio.mit.edu/education.html

http://www.synberc.org/content/articles/what-synthetic-biology

Title	**Ordinary Differential Equations**	Number	MAL6XX0
Department	Mathematics	L-T-P [C]	3–0–0-1[4]
Offered for	M.Tech	Type	Elective
Prerequisite	Nil		

Objectives

1. Introduce the concepts of existence and uniqueness of solution of ordinary differential equations

2. Develop analytical techniques to solve ordinary differential equations

3. Understand the properties of solution of ordinary differential equations

Learning Outcomes

1. Understanding existence, uniqueness, and other properties of a solution of ordinary differential equations

2. Solving ordinary differential equations with series method, Green's function method

3. Solving systems of ODEs, and characterization of their solutions

Contents

Motivations and origins, Existence-Uniqueness [7 Lectures]: Existence of solutions by Picard's method, uniqueness and continuous dependence w.r.t. initial conditions and parameters, continuation of solutions, existence and uniqueness of solutions to system of differential equations.

Second Order Linear Equations [23 Lectures]: General solution of differential equations using method of undetermined coefficients, method of variation of parameters, variable coefficients equations, Power series solution method, Legendre's equation, Frobenius method, Bessel's equation, Green's function method, Sturm-Liouville problems, orthogonal eigen-function expansions, Sturm comparison theorem, Sturm separation theorem,

Systems of Differential Equations [10 Lectures]: Phase plane method, critical points of the system and their stability analysis, algebraic properties of solutions, the eigenvalue-eigenvector method of finding solutions, fundamental matrix solutions, matrix exponential, nonhomogeneous equations.

Text Books

1. Ross, S. L., Introduction to ordinary differential equations, 4th Ed., John Wiley Publications, 1989

2. Braun. M., Differential Equations and Their Applications, 3rd Ed., Springer-Verlag, 1983

3. Chicone, C., Ordinary Differential Equations with Applications, 2nd Ed., Springer, 2006

Reference Books

1. Coddington, E. A., An Introduction to Ordinary Differential Equations, PHI Learning 1999

2. Birkhoff, G. and Rota G., Ordinary Differential Equations, 4th Ed., Wiley Publications, 1989

3. Simmons, G., Differential Equations with Applications and Historical Notes, 2nd Ed., McGraw Hill Education, 2017

Online Course Material

1. Agrawal, P. N. and Pandey, D. N. (IIT Roorkee), Ordinary and partial differential equations and applications, https://nptel.ac.in/courses/111107111/

2. Raghavendra V. (IIT Kanpur), Ordinary differential equations , https://nptel.ac.in/courses/111104031/

Title	**Numerical Methods for PDE**	Number	MAL7XX0
Department	Mathematics	L-T-P [C]	1–0–0-0 [1]
Offered for		Type	Elective
Prerequisite			

Objectives

The Instructor will

1. Introduce finite difference schemes for numerical solutions of partial differential equations.

2. Carry out numerical analysis of various finite difference schemes.

Learning Outcomes

The students are expected to have the ability to:

1. Apply finite difference schemes for numerical solution of partial differential equations.

2. Undertake out error analysis and stability analysis of finite difference schemes

Contents

[8 Lectures] Characterization of PDEs, Finite difference methods for elliptic, parabolic and hyperbolic problems.

[6 Lectures] Stability, consistency and convergence theory, dissipation and dispersion, error estimates.

Text books

1. Quarteroni, A. and Valli, A. , Numerical Approximation of Partial Differential Equations, Springer, 1997

2. Morton, K. W. and Mayers, D. F. , Numerical solution of partial differential equations, CUP, 2005

Reference Books

1. Thomas, J. W. , Numerical partial differential equations: Finite difference methods, Springer, 1995

2. Trefethen, L. N. and David Bau III, Numerical Linear Algebra, SIAM, 1997

Online Course Material

1. Nayak, A. K. , Numerical methods: Finite Difference Approach, NPTEL Course Material, Department of Mathematics, Indian Institute of Technology Roorkee, https://nptel.ac.in/courses/111107107/

Title	**Flux Balance Analysis**	Number	BBL7XX0

Department	Bioscience and Bioengineering	L-T-P [C]	3–0–0[3]
Offered for	M.Tech	Type	Elective
Prerequisite	Nil		

Objectives

The Instructor will:

1. Provide an introduction to flux balance analysis (FBA), reactions, metabolites, & pathways, mass balanced linear equations, biomass reaction, how to create a stoichiometric matrix from reactions and metabolites, gene-protein-reaction associations, constraint-based modeling.

Learning Outcomes

The students are expected to have the ability to:

1. Implement knowledge of important concepts related to the FBA

2. To apply them to model the behavior of biological systems as well as develop strategies for manipulating them.

Contents

Flux Balance Analysis Overview: Overview, Formulation of Flux Balance Analysis [1 Lecture]

Reactions, Metabolites, & Pathways: Identifying Metabolic Reactions and Metabolites (Gene-Protein-Reactions), Desired Reaction Information, Genome-scale Reconstruction Reactions, Desired Metabolite Information, Genome-scale Reconstruction Metabolites, Metabolic Pathway, System Boundaries:Exchange & Transport Reactions, Genome-scale Metabolic Reconstructions, Reconstruction Process: 96 Step Protocol, E.coli Core Model [14 Lectures]

Mathematical Representation of Reactions & Constraints: Creating A Stoichiometric Matrix, Genome-scale Metabolic Reconstruction [2 Lectures]

Mass Balanced Linear Equations: How can we use the Stoichiometric Matrix?, Dynamic Mass Balance, The Conceptual Basis of Constraint-based Modeling, Role of Constraints, Flux Optimization [6 Lectures]

Biomass Reaction: Biomass Precursors, E.coli Precursor Metabolites, Maintenance Energy Requirements, Biomass Reaction For E.coli Core Model, Biomass Objective Function, Formulation of Flux Balance Analysis, E.coli Core Model [8 Lectures]

Calculating Fluxes: Cobra Toolbox, Matlab, Drawing Flux Values on a Map, Print Flux Values, Examples [8 Lectures]

Flux Balance Analysis Toolbox: Methods in Constraint-based Reconstruction and Analysis [3 Lectures]

Textbook

1.Palsson B. O., (2006), Systems Biology: Properties of Reconstructed Networks, cambridge Press.

Self Learning Material

1. Utah State University, https://systemsbiology.usu.edu/syllabus.php

Preparatory Course Material

1. Department of Biotechnology, Indian Institute of Technology Madras,

https://nptel.ac.in/noc/individual_course.php?id=noc18-bt22

Title	**Systems Biology in Personalized Genomics**	Number	BBL7XX0
Department	Bioscience and Bioengineering	L-T-P [C]	3–0–0[3]
Offered for	M.Tech	Type	Elective
Prerequisite	Nil		

Objectives

The Instructor will:

1. Illustrate “big-data” problems in personalized genomics by discussing recent publications

2. Provide training in high dimensional biological data analysis

3. Familiarize the participants with the use of statistical tools and principles for analyzing genomic/epigenomic data

Learning Outcomes

It will enable participants to utilize the methods presented in this course for analyzing biological data. The course introduces the current research challenges faced in the field of computational systems biology.

Contents

Course Overview and Introduction: Design Principles of Complex Systems, Introduction to Genomics and Systems Biology [2 lectures]

Topological and Network Evolution Models: Small-World and Scale-Free Networks, Duplication-Divergence, Complex Models of Network Evolution, Network Properties of Biological Networks [6 lectures]

Types of Biological Networks: Types of Biological Networks, Genes2Networks and Network Visualization, Sets2Networks - Creating Functional Association Networks, Genes2FANs - Analyzing Gene Lists with Functional Association Networks [4 lectures]

Data Processing and Identifying Differentially Expressed Genes: Data Normalization, Univariate and multivariate methods for identifying differentially expressed gene sets - Part 1, Univariate methods (SAM, Welch’s t-test, LIMMA,) - Part 2, Multivariate method (Principal Component Analysis; Gene Set Enrichment Analysis; Supervised and unsupervised machine learning for data classification, including Clustering, SVM and KNN) [15 lectures]

Analytical Tools for Genomics: Enrichment Analysis and Enrichr, GEO2Enrichr: A Google Chrome Extension for Gene Set Extraction and Enrichment, Gene Set Enrichment Analysis (GSEA) - Preliminaries, Gene Set Enrichment Analysis (GSEA), Principal Angle Enrichment Analysis (PAEA), Network2Canvas (N2C) and Enrichment Analysis with N2C, Expression2Kinases: Inferring Pathways from Differentially Expressed Genes, DrugPairSeeker and the New CMAP, Classifying Patients/Tumors from TCGA [15lectures]

Textbook

1. Ma'ayan A. and MacArthur B. D. (eds.) (2012), New Frontiers of Network Analysis in Systems Biology, Springer.

Reference Books

Research literature

Self learning materials

1. Mount Sinai Center for Bioinformatics, https://www.coursera.org/learn/network-biology

Title	**Artificial Intelligence in Bioengineering Lab**	Number	BBP7XX0
Department	Bioscience & Bioengineering	L-T-P [C]	0-0-2 [1]
Offered for		Type	Open Elective
Prerequisite	Machine Learning-1		

Objective:

The instructor will:

1. prepare industry relevant advanced cross-disciplinary skills in machine learning applications in bioengineering.

Learning Outcome

The students will have an ability to:

1. comprehend fundamental concepts and hands-on techniques of the state-of-the-art data science and deep learning methodologies
2. apply popular unsupervised learning methods, including clustering methodologies and supervised methods such as deep neural networks
3. master techniques in modern data analysis to leverage big datasets from omics, image and sensors; use pyspark skillfully to analyze big data

Laboratory Experiments

Introduction: data types, big data processing using pyspark (3 labs)

Machine learning applications: supervised and unsupervised techniques for omics data integration and analysis (4 labs)

Deep learning: applications in omics, image and sensor data (7 labs)

Textbook

1. Shalev-Shwartz,S., Ben-David,S., (2014), *Understanding Machine Learning: From Theory to Algorithms*, Cambridge University Press

2. Tseng,G., Ghosh,D., Zhou X.J., (2015), *Integrating Omics Data,* Cambridge University Press

Self-Learning Material

1. Department of Computer Science, Stanford University

https://see.stanford.edu/Course/CS229

Preparatory Course Material

1. https://www.tutorialspoint.com/pyspark/

Program Elective Set 5

Biomaterials Engineering

Title	**Biophysics**	Number	BBL7XX0
Department	Bioscience & Bioengineering	L-T-P [D]	2-0-0 [2]
Offered for	M.Tech Students	Type	Elective
Prerequisite	Nil		

Objectives:

1. To learn the fundamentals of biological problems tackled by biophysicists ranging from the structure of small molecules to organs or physiological functions.

Learning Outcome:

The students will have an ability to

1. Understand selected biological phenomena using physical principles.
2. Utilize physical methods in the study of biological systems.

Content*:*

Introduction: Forces in living system, Thermodynamics of living systems; Conservation of energy in living systems, Entropy and Life, Gibbs and Standard free energy, Equilibrium constant, Coupled reactions.(7 lectures)

Conformational stability of biomolecules: Forces for protein stability, Protein denaturation and renaturation, Protein folding pathways, Levinthal's paradox, Molten globule, Folding accessory proteins, structural stability of DNA and RNA, biophysics of chromatin packing (7 lectures)

Molecular self-assembly: Organization of lipids in aqueous environment, Formation of vesicles, Transport of biomolecules: Diffusion, Osmosis, Facilitated diffusion, Active transport, function of ion channels Biophysical properties of cell membrane: Membrane potential, Action potential and resting phase. (7 lectures)

Bioimpedance and biopotentials Cell motility: mechanism of pseudopodia formation and ciliary movement, muscle contraction Cellular mechanotransduction, tensigrity model for bone remodeling, flow induced shear stress Molecular Techniques used in biophysics: Atomic force microscopy, optical tweezers, patch clamp, FRET, confocal microscopy, super resolution microscopy, XRD and NMR. (7 lectures)

Textbook:

Cotterill Rodney M.J., (2014) *Biophysics:introduction*, John Wiley ISBN-13: 978-8126551606

Reference book:

Leake, M.C., (2017) *Biophysics: Tools and Techniques* 1st edition CRC Press ISBN-13: 978-1138407374

Self-learning Material:

https://www.biophysics.org/education-careers/education-resources/additional-education-resource

Title	**Materials characterization**	Number	MTL6XX0
Department	Material Science & Engineering	L-T-P [C]	1–0–0 [1]
Offered for	M.Tech	Type	Elective
Prerequisite	Nil		

Objectives

The Instructor will:

1.Provide introduction to surface chemistry and physics of selected metals, polymers, and ceramics; surface characterization methodology; modification of biomaterials surfaces; quantitative assays

Learning Outcomes

The students are expected to have the ability to:

1. understand areas of application based on bulk properties of implants; and acute and chronic response to implanted biomaterials. General topics include biosensors, drug delivery, and tissue engineering.

Contents

*Introduction to the interactions between cells and the surfaces of biomaterials*Surface chemistry and physics of selected metals, polymers, and ceramics; surface characterization methodology; modification of biomaterials surfaces; quantitative assays of cell behavior in culture; biosensors and microarrays; bulk properties of implants; and acute and chronic response to implanted biomaterials. General topics include biosensors, drug delivery, and tissue engineering. Experiments illustrating the principles of quantum mechanics, thermodynamics and structure with intensive oral and written technical communication practice. Specific topics include: experimental exploration of the connections between energetics, bonding and structure of materials, and application of these principles in instruments for materials characterization; demonstration of the wave-like nature of electrons; hands-on experience with techniques to quantify energy (DSC), bonding (XPS, AES, FTIR, UV/Vis and force spectroscopy), and degree of order (x-ray scattering) in condensed matter; and investigation of structural transitions and structure-property relationships through practical materials examples. (14lectures)

Textbook

1.Ikada, Y., and H. Tsuji(2000), *Biodegradable Polyesters for Medical and Ecological Applications*. Macromolecular Rapid Communications 21: 117-132

2. Marazuela, M. D., and M. C. Moreno-Bondi (2002). *Fiber-optic Biosensors - An Overview*. Analytical and Bioanalytical Chemistry 372: 664-682.

Self Learning Material

1. Mayes, A. *Materials for Biomedical Applications* MIT OpenCourseWare Massachusetts Institute of Technology, https://ocw.mit.edu. License: Creative Commons BY-NC-SA

Title	**Tissue Engineering & Medical Device Implants**	Number	BBL7XX0

Department	Bioscience & Bioengineering	L-T-P [C]	3-0-0 [3]
Offered for	M.Tech Students	Type	Elective

Objective:

1. The major objective of the course would be to give a brief introduction of Tissue Engineering, Medical Device & Implants and insights onto their use for generation of Medical Devices. Highlight current understanding, challenges and future applicative potentials of Medical Device & Implants.

Learning Outcomes:

The students will have an ability to:

1. Students completing the course would gain an introductive experience of the field and able to comprehend with common terminologies.

Contents:

BBL7XX1: Tissue engineering and dynamics [1-0-0]

(fractal, 1) *Tissue Engineering Introduction:* Introduction to tissue engineering, Cells as therapeutic Agents with examples, Cell numbers and growth rates Tissue organization, Tissue Components, Tissue types, Functional subunits. (7 lectures)

Tissue Dynamics: Dynamic states of tissues, Homeostasis in highly prolific tissues and Tissue repair. Angiogenesis. Cell-extracellular matrix interactions - Binding to the ECM, Modifying the ECM, Malfunctions in ECM signaling. Direct Cell-Cell contact - Cell junctions in tissues, malfunctions in direct cell-cell contact signaling. Response to mechanical stimuli (7 lectures)

BBL7XX2: Measurements of cell characteristics and Biomaterials 1 [1-0-0]

(fractal, 2) *Measurement of cell characteristics:* Cell morphology, cell number and viability, cell-fate processes, cell motility, cell function. Cell and tissue culture - types of tissue culture, media, culture environment and maintenance of cells in vitro, cryopreservation. Basis for Cell

Separation, characterization of cell separation, methods of cell separation (7 lectures)

Biomaterials in tissue engineering: Biodegradable polymers and polymer scaffold processing.

In vivo cell & tissue engineering case studies: Artificial skin, Artificial blood vessels, Artificial

Pancreas, Nerve Regeneration (7 lectures)

BBL7XX3: Medical devices and implants [1-0-0]

(fractal, 3) *Medical Device & Implants Introduction:* Medical Device Classification, Bioethics and Privacy, Biocompatibility and Sterilization Techniques*. Concept Design and Principles of Medical Device:Implants and Clinical Tools: Design Control & Regulatory Requirements. Introduction to specific medical technologies* (7 lectures)

Biopotentials measurement: EMG, EOG, ECG, EEG, Medical Diagnostics (In-vitro diagnostics), MedicalDiagnostics (Imaging), Minimally Invasive Devices, Surgical Tools and Implants (7 lectures)

Textbook

1. Lanza, R., Langer, R., Vacanti, J., (2018), *Principles of Tissue Engineering*, 4th Edition, eBook

Self Learning Material

1.Swaminathan, S., *Tissue Engineering*, Sastra University,

https://nptel.ac.in/courses/102106036/#

Preparatory Course Material:

1. **Design of BioMedical Devices and Systems, Utsaah University,**
http://cpdm.iisc.ac.in/utsaah/pd233/

Title	**Thermodynamics & Kinetics of Materials – Material properties**	Number	MTL6XX1
Department	Material Science & Engineering	L-T-P [C]	1–0–0 [1]
Offered for	M.Tech	Type	Elective
Prerequisite	Nil		

Objectives

The Instructor will:

1.Provide introduction to thermodynamics and kinetics of materials and their effect on material properties

Learning Outcomes

The students are expected to have the ability to:

1. understand areas of application based on thermodynamic properties

Contents

*Treatment of the laws of thermodynamics and their applications to equilibrium and the properties of materials***.** Provides a foundation to treat general phenomena in materials science and engineering, including chemical reactions, magnetism, polarizability, and elasticity. Develops relations pertaining to multiphase equilibria as determined by a treatment of solution thermodynamics. Develops graphical constructions that are essential for the interpretation of phase diagrams. Treatment includes electrochemical equilibria and surface thermodynamics. Introduces aspects of statistical thermodynamics as they relate to macroscopic equilibrium phenomena (14 lectures).

Textbook

1. Ikada, Y., and H. Tsuji(2000), *Biodegradable Polyesters for Medical and Ecological Applications.* Macromolecular Rapid Communications 21: 117-132

2. Marazuela, M. D., and M. C. Moreno-Bondi (2002). *Fiber-optic Biosensors - An Overview*. Analytical and Bioanalytical Chemistry 372: 664-682.

Self Learning Material

1. Mayes, A. *Materials for Biomedical Applications* MIT OpenCourseWare Massachusetts Institute of Technology, https://ocw.mit.edu. License: Creative Commons BY-NC-SA

Title	**Computational modelling in materials design**	Number	MSL7XX0
Department	Materials Science & Engineering	L-T-P [C]	1–0–0 [1]
Offered for	M.Tech	Type	Elective
Prerequisite	Nil		

Objectives

The Instructor will:

1. Provide introduction to modeling and simulation, covering continuum methods, atomistic and molecular simulation, and quantum mechanics.

2. Provide Hands-on training is provided in the fundamentals and applications of these methods to key engineering problems.

Learning Outcomes

The students are expected to have the ability to:

1. Understand areas of application based on the scientific exploitation of the power of computation.

Contents

Energy models from classical potentials to first-principles approaches: Energy models from classical potentials to first-principles approaches; density functional theory and the total-energy pseudo-potential method; errors and accuracy of quantitative predictions: thermodynamic ensembles, Monte Carlo sampling and molecular dynamics simulations; free energy and phase transitions; fluctuations and transport properties; and coarse-graining approaches and mesoscale models. (7lectures).

Case studies from industrial applications of advanced materials to nanotechnology:

Several laboratories will give students direct experience with simulations of classical force

fields, electronic-structure approaches, molecular dynamics, and Monte Carlo. (7lectures).

Textbook

1.Dieter,G.E., (1986), *Mechanical Metallurgy*, 3rd Edition, McGraw Hill Book Company

2. Courtney,T.H., (2005), *Mechanical Behaviour of Materials*, 2nd Edition, Waveland Press Inc.

3. Shetty,M.N., (2013), *Dislocations and Mechanical Behaviour of Materials*, Prentice Hall India Learning Private Limited

Self-Learning Material

1. Bauri,R., *Introduction to Materials Science and Engineering,* NPTEL Course Material, Department of Metallurgical & Materials Engineering, Indian Institute of Technology Madras, http://nptel.ac.in/courses/113106032/

2. vanVliet,K., *3.22 Mechanical Behavior of Materials*, Spring 2008, MIT OpenCourseWare Massachusetts Institute of Technology, https://ocw.mit.edu. License: Creative Commons BY-NC-SA

Title	**Biomechanics**	Number	BBL7XX0
Department	Bioscience & Bioengineering	L-T-P [D]	2-0-0 [2]
Offered for	M.Tech Students	Type	Elective
Prerequisite	Nil		

Objective:

The instructor will:

1. Elucidate the role of Biomechanics in the field of Bioscience & Bioengineering with special emphasis on use in improving tissue repair and regeneration.

Learning Outcome:

The students will have an ability to:

1. Understand and apply Biomechanics and their Fundamental Principles.

2. Design the cutting edge applications of Biomechanics

Contents

Introduction to Biomechanics: Cellular Mechanics Static and dynamic cell processes; Cell adhesion, migration and aggregation; Mechanics of bio-membranes (7 lectures)

Cytoskeleton and cortex: Microrheological properties and their implications; Mechanotransduction; Experimental methods - passive and active rheology, motility and adhesion assays (7 lectures)

Tissue Mechanics: Elastic (time independent); viscoelastic and poro-elastic (time-dependent) behavior of tissues; Continuum and microstructural models; Constitutive laws; Electromechanical and physicochemical properties of tissues; Physical regulation of cellular metabolism; Experimental methods - macroscopic rheology (14 lectures)

Textbook

1. Huston, R.L., (2014) *Principles of Biomechanics*, CRC Press

2. Koeppen, M., Bruce, A., Mosby, B., (2009) *Stanton Berne & Levy Physiology*, 6th Edition,

Online Course Material

https://nptel.ac.in/syllabus/112106059/

Title	**Biomaterials and Bioengineering**	Number	BBL7XX0

Department	Bioscience & Bioengineering	L-T-P [C]	3-0-0 [3]
Offered for	M.Tech	Type	Elective
Prerequisite	None		

Objective

The Instructor will:

1. inspire future potential of bioengineering discipline

2. provide cutting edge knowledge and applications of biomaterials in tissue engineering, drug delivery, biomechanics and reconstitution various biological events

Learning Outcome

The students are expected to have the ability to:

1. understand how biomaterials are useful for various biotechnological and bioengineering applications

Contents

Background and definition of biomaterials: classes of materials used biotechnological applications and in medicine: polymers, metals, ceramics, natural materials and composites, biodegradable polymers in medicine: polymers, liposomes, hydrogels, silicone biomaterials and medical fibers, degradation of materials in the biological environment, types of polymer degradation. influence of polymer properties on degradation, influence of biological environment on polymer degradation (14 lectures)

Surface engineering of biomaterials: biological testing of biomaterials: in vitro assessment of materials for tissue compatibility, in vivo assessment of tissue compatibility. host reactions to biomaterials and their evaluations, the role of adsorbed proteins in tissue response to biomaterials. cell, extra cellular matrix, and tissue interactions with biomaterials, inflammation, wound healing and foreign body response to biomaterials. immune response to foreign materials. toxicity, tumor genesis and biomaterials (14 lectures)

Microscopes for monitoring biomaterials and their dynamics: tirf and confocal, applications in drug delivery and nanomedicine, bioengineering concept to reconstitute cell like micro-chambers: flow-chambers and artificial cell, bioengineered platform for monitoring microtubule dynamics, bioengineered platform for monitoring microtubule motility and organization, bioengineered platform for monitoring microtubule force, reconstitution of kinesin transport using engineered biomaterials, applications in brain injury, repairing and future applications (14 lectures)

Textbook

1. Latest Research articles (ChemBioChem, Molecular Biosystem, AngewChem, ACS Chemical Biology, JACS, ChemComm, ACS Chemical Neuroscience etc.)

Self Learning Material

None

Preparatory Course Material

None

Program Elective Set 6

Bioenergy & Environmental Technologies

Title	**Bioenergy Systems**	Course	BBL7XX0
Department	Bioscience and Bioengineering	L-T-P [C]	3-0-0 [3]
Offered for		Type	Elective
Prerequisite			

Objectives

The instructor will:

1. Acquaint students with the principles and applications of bio-energy harnessing systems ranging from conventional processes to the latest developments in the area

2. Enable students integrate two or more renewable energy processes to achieve a sustainable energy harvesting system

Learning Outcomes

The students will have an ability to:

1. Utilize biomass as sustainable fuel

2. Utilize the knowledge of bioenergy systems while integrating bioenergy with other renewable energy systems

Contents

Overview: Different bio-energy systems, sustainable bio-energy, different types of biomass (including forestry residues) and their processing, Principles of bio-energy harnessing by nature, Photosynthesis-natural solar energy capture process *(6 lectures)*

Anaerobic fermentation technology: Biogas production, process, microbiology, different types of bioreactors, basic process kinetics*(8 lectures)*

Biomass gasification technology: Syngas production process, different types of gasification reactors, factors affecting the process *(6 lectures)*

Liquid biofuels [6 lectures]: Various types of biofuels,1st and 2nd generation biofuels, Algal Biofuels, ASTM standards for biofuels, Basic biochemical processes, engineering of biofuel producing organisms, metabolic engineering *(6 lectures)*

Microbial fuel cells: Basic principle, Bioelectricity and different reactor configurations *(4 lectures)*

Artificial photosynthesis: Mimicking natural solar energy capture process, biohydrogen *(3 lectures)*

Downstream processes for product recovery: Basic processes like filtration, centrifugation, and solvent extraction*(5 lectures)*

Applications: Technical uses of bioenergy, Systems Approaches to Bio-fuels Sustainability, positive environmental implications of bioenergy systems, Commercialization and

Economics of bio-energy technologies *(4 lectures)*

Textbooks

1. Vertes, A. A., Qureshi, A., Yukawa, H., Blaschek, H.P.,(2010) *Biomass to Biofuels,* Wiley.
2. German Solar Energy Society, Ecofys, (2006) *Planning and installing bioenergy systems: A guide for installers, architects and engineers*, Earthscan,

Reference Books

1. Stanier, R. Y., (2009) *General Microbiology*, W.H. Freeman and Co.

2. Pelczar, M.J., Chan, E. C. S., Krieg, N.R.,(2001) *Microbiology*, Tata McGraw - Hill Education

Online course material

1. Michelle O'Malley, *Fueling Sustainability: Engineering Microbial Systems for Biofuel Production,* Spring 2011, MIT OpenCourseWare Massachusetts Institute of Technology, https://ocw.mit.edu. License: Creative Commons BY-NC-SA

Title	**Environmental Biotechnology and Bioremediation**	Number	BBL7XX0
Department	Bioscience and Bioengineering	L-T-P [C]	3–0–0 [3]
Offered for		Type	Compulsory
Prerequisite			

Objectives

The instructor will:

1. acquaint students with the way wastes/wastewaters as well as toxic wastes are treated

2. teach methods pertaining to sustainable wastewater recycling

Learning Outcomes

The students will have an ability to:

1. Understand increasing water, soil or air pollution because of industrialization and how biotechnology can circumvent these problems

2. design a treatment process based on the characteristics of the wastewater to be treated

Contents

Introduction: Basics of Microbiology, Stoichiometry and Bacterial energetics *(5 lectures)*

Kinetics and Reactors: Microbial Kinetics and Biofilm kinetics, Reactor types, Mass balances, Batch reactor, Continuous stirred tank reactor *(7 lectures)*

The activated sludge process: Characteristics of activated sludge, Process configurations, Design and operating criteria, aeration systems and sludge separation *(5 lectures)*

Nitrification and denitrification: Bacterial physiology and basic process including biofilm and hybrid (4 lectures)

Phosphorus removal: Normal phosphorus uptake into biomass, precipitation and enhanced biological removal (4 lectures)

Drinking water treatment: Aerobic biofilm processes to remove biological instability, biodegradation and denitrification (4 lectures)

Anaerobic treatment by methanogenesis: Reactor configurations, Process chemistry and Microbiology, Process kinetics (4 lectures)

Detoxification of hazardous chemicals: Molecular recalcitrance, Biodegradation of problem environmental contaminants (4 lectures)

Bioremediation: Scope and characteristics of contaminants, Biodegradability, Treatability studies, Engineering strategies for bioremediation, Biotechnological and genetics engineering approaches-creations of superbugs (4 lectures)

Textbooks

1. Rittmann, B.E., McCarty, P.L., (2001) *Environmental Biotechnology: Principles and Applications* ,Tata McGraw Hill.

Reference books

1. Shuler, M., Kargi, F., (2002)*Bioprocess Engineering: Basic Concepts*, 2nd edition Prentice Hall.
2. Stanier, R. Y., (2009) *General Microbiology*, W.H. Freeman and Co.

Online course material:

1. Gargi Singh, Applied Environmental Microbiology, NPTEL Course Material, Department of Civil Engineering, Indian Institute of Technology, Roorkee, http://nptel.ac.in/courses/105107173/

Title	**Bio-electrochemical Systems**	Number	BBL7XX0
Department	Bioscience and Bioengineering	L-T-P [C]	2–0–0 [3]
Offered for	B Tech.	Type	Compulsory
Prerequisite			

Objectives

1. The instructor will acquaint students with Microbial fuel cell technology and the merits associated with the technology

Learning Outcomes

The students will have an ability to:

1. utilize microorganisms with electricity production and design bioelectrochemical systems for various applications

2. understand a system involving electrochemistry, Microbiology, material Science & Chemical Engineering all in one go.

Contents

Introduction: Introduction to bio-electrochemical systems *(2 lectures)*

Electrochemistry: The Nernst equation and electrochemical potential difference, the redox reactions, calculating and measuring potentials *(3 lectures)*

Microbiology: The exoelectrogenic microbes, microbial physiology, the electron donors, the electron acceptors. *(3 lectures)*

Components & configuration: the anode, cathode, membrane, the connections, double chambered, Single chamber, air cathode and sediment type MFCS (*3 lectures)*

Characterization: Electrochemical sensors, chronoamperometry, cyclic voltammetry, differential pulse voltammetry, Electrochemical Impedance spectroscopy, Optical Sensors, colorimetry, fluorescence (7 lectures)

Applications of bio-electrochemical systems: Power generation, water treatment, bioremediation *(4 lectures)*

Bio electrochemical system for Hydrogen production: Integrating MFCs with external power to generate hydrogen (*2 lectures)*

Scope and the future: Integration of MFC with other energy generation technologies (*4 lectures)*

Textbooks

1. Rittmann, B.E., McCarty, P.L., (2001) *Environmental Biotechnology: Principles and Applications* ,Tata McGraw Hill.

Reference books

1. Shuler, M., Kargi, F., (2002) *Bioprocess Engineering: Basic Concepts*, 2nd edition Prentice Hall.
2. Stanier, R. Y., (2009) *General Microbiology*, W.H. Freeman and Co.

Online course material:

Title	**Environmental Microbiology**	Number	BBL7XX0
Department	Bioscience and Bioengineering	L-T-P [C]	2-0-0 [2]
Offered for		Type	Compulsory
Prerequisite			

Objectives

The instructor will:

1. Enable students utilize the knowledge of Microbiology for environmental cycling and enhanced agriculture productivity.

Learning Outcomes

The students will have an ability to:

1. Understand the ecological interactions of Microbes in detail and will be able to associate the structure and function of a particular microbial community in a particular environment.
2. Understand the soil plant interactions, how microbes make nutrients available for plant growth and how that helps in enhanced crop productivity.

Contents

Environmental and Agricultural microbiology: Microbial Ecology, Microbial Evolution and Biodiversity, Interactions among Microbial Populations, Interactions between Microorganisms and Plants, Plant growth promoting bacteria, Microbial Interactions with Animals, Microbial Communities and Ecosystems, Measurement of Microbial Numbers, Biomass, and Activities, Effects of Abiotic Factors and Environmental Extremes on Microorganisms, Microorganisms in Their Natural Habitats: Air, Water, and Soil Microbiology, Biogeochemical cycling, soil, waste, water management, Microorganisms in Mineral and Energy Recovery and Fuel and Biomass Production. (28 lectures)

Textbook

1. Atlas, R.M., Bartha, R., (2001) Microbial Ecology: Fundamentals and applications, Pearson
2. Jawetz, Melnick, Adelberg (2018) Medical Microbiology, 28th Edition McGraw Hill

Reference Books

1. Brock, et al., (2012), Biology of Microorganisms, 13th edition Ben,jamin Cummings, Boston, MA.

2. Lehninger, A., Nelson, D.L., Cox, M., (2009) Principles of Biochemistry, W.H. Freeman and Co.

Online course material

1. David Schauer, and Edward DeLong. *20.106J Systems Microbiology.* Fall 2006. Massachusetts Institute of Technology: MIT OpenCourseWare, https://ocw.mit.edu.

Title	Water Energy Nexus	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P	3-0-0
Offered for	M. Tech and PhD	Type	Program Elective

Objectives:

1. Course designed to understand relation of energy of water use in our daily lives as well as water use for energy and food production.

2. To enable plan pathways of water life cycle according the end-use requirements in municipal/ agriculture/ industrial environments. .

Learning Outcomes:

1. Ability to design energy/cost optimized systems according to location specific end-use requirements and water availability

2. To have capability to locate correct locations where energy intensity as well as water efficiency measurements of the water transport within systems can be performed.

Contents:

Introduction to energy-water nexus: Hydro-electric power production, Water Life Cycle in the different economic sectors

Energy intensity (Joule/Litre etc.) definition, Equivalent electrical energy intensity [kWh/m3], Basic unit conversion, factors of energy conversion from thermal to electrical & vice versa

Water extraction from ground as well as surface. Pumping efficiency, effect of lift and other influencing parameters, Different modes of surface water transfer.

General overview of conventional water treatment energy use, Intro to thermal desalination, Membrane desalination systems, hybrid desalination systems .Renewable and non-renewable sources of energy and its influence of energy intensity .

Discussion on water end-use based electrical and thermal energy consumption. Electricity consumption in Residential water use: Clothes Washing, doing dishes, heating water, cooking water based foods. Commercial buildings and Energy use; Do buildings consume energy or the people within, Human behaviour and variation in energy consumption.

Waste water recycling: review, of equivalent electrical energy intensity and operation of waste water treatment plant equipment and technologies.

Agricultural water use and their energy intensity: Energy intensity of irrigation water use with change in crops; change in irrigation technology, subsidy in electricity, human behavior; with variation in geographic land scape.

Case study of water life cycle in various locations: USA, Ontario, Canada, China, Australia, India.

Text books :

1. C. Sommariva: Desalination Desalination and Advanced Water Treatment: Economics and Financing, First ed., Balaban Desalination Publications, Hopkinton, MA, USA, 2010.pg. 103.
2. A K Plappally and J H Lienhard Energy Requirements for Water Production, Treatment, End Use, Reclamation, and Discharge, Renewable and sustainable energy reviews (RSER), 16(1)

Self-learning Material:

1. Sustainable Development: The Water Energy Food Nexus Aachen Universityhttps://www.edx.org/course/sustainable-development-the-water-energy-food-nexus
2. Water-Energy Nexus Course of Studies at Irvine,https://www.water-energy-food.org/resources/resources-detail/university-of-california-water-energy-nexus-urse-of-studies-at-irvine/