M. Tech
in
Biotechnology
&
Biochemical Engineering

OFFERED

BY

DEPARTMENT OF BIO ENGINEERING

NIT-AGARTALA

VISION

To Produce the Bright Young Professionals by Quality Education & Research in the Emerging Field of Biotechnology & Biochemical Engineering to Fulfill the Societal Commitments at par with Global Standards.

MISSION

- To produce highly motivated, competent young Professionals in the Biotechnology and Biochemical engineering field of national and international standards fulfilling professional ethics and social commitments.
- Prepare graduates of the programme to meet the growing demands for continued development and entrepreneurship in the biochemical and biotechnological industry
- Provide a mechanism for students to increase their competitiveness in attaining admission for further studies including Phd Programs.
- Implementation of gained knowledge and technologies in the regions of North eastern state of India.

PEOs (Programme Educational objectives)

- To apply Basic Sciences, Mathematics, and Engineering to solve advanced biotechnological problems.
- To proficiently design and evaluate experiments, systems, components, or processes to meet desired needs and expectations on global context.
- To understand and establish professional ethics, with social responsibility to become successful graduate in the field of biotechnology and biochemical engineering.
- To pursue higher studies in the respective field and develop as an entrepreneur.

PSOs (Program Specific Outcomes)

- To gain knowledge in several protocols and professional techniques for application in bio-industries and bio-entrepreneurship.
- To acquire in-depth knowledge in various research and developmental activities for social welfare.

PO (Program Outcomes)

PO-1	An ability to independently carry out research /investigation and development work to solve practical problems.
PO-2	An ability to write and present a substantial technical report/document.
PO-3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.
PO-4	To gain knowledge in several protocols in biochemical engineering and professional techniques for application in biotechnological industries and bio-entrepreneurship.
PO-5	To acquire the skill and knowledge sets in the areas of biotechnological research, innovation and business to benefit the societal needs.
PO-6	To be able to apply knowledge of biotechnology and biochemical engineering for the advancement of science and technology.

M. TECH in BIOTECHNOLOGY & BIOCHEMICAL ENGINEERING

Proposed Course Structure

SEMESTER-I

Sl. No	CODE	SUBJECT	L-T-P	CREDIT
1		Bioanalytical Techniques	3-1-0	4
2		Biotechnology and Biochemical engineering Principles	3-1-0	4
3		Genomics and Proteomics	3-1-0	4
4		Applied Bioinformatics	3-1-0	4
5		Elective 1	3-1-0	4
6		Bioanalytical Techniques Lab	0-0-3	2
7		Applied Bioinformatics Lab	0-0-3	2
8		Seminar	0-0-2	1
		Total	**28**	**25**

SEMESTER-II

Sl. No	CODE	SUBJECT	L-T-P	CREDIT
1		Bioreactor Design and Analysis	3-1-0	4
2		Bioseparation Technology	3-1-0	4
3		Elective 2	3-1-0	4
4		Elective 3 (Open)	3-1-0	4
5		Biotechnology and Biochemical engineering Lab	0-0-3	2
6		Bioprocess and Bioseparation Technology Lab	0-0-3	2
7		Project Preliminary	0-0-6	3
8		Comprehensive Viva Voce	0-0-0	2
		Total	**28**	**25**

SEMESTER-III

Sl. No	CODE	SUBJECT	L-T-P	CREDIT
1		Project And Thesis-1	0-0-20	10
		Total	**20**	**10**

SEMESTER-IV

Sl. No	CODE	SUBJECT	L-T-P	CREDIT
1		Project And Thesis-2	0-0-40	20
		Total	**40**	**20**

- **Distribution of credit semester wise**

SL No	SEMESTER	CREDIT
1	I	25
2	II	25
3	III	10
4	IV	20
	Total	**80**

Theory Courses (Semester I and Semester II)

Sl. No	Code	SUBJECT	Credit	Marks
1		Bioanalytical Techniques	4	100
2		Biotechnology and Biochemical engineering Principles	4	100
3		Genomics and Proteomics	4	100
4		Applied Bioinformatics	4	100
5		Bioreactor Design and Analysis	4	100
6		Bioseparation Technology	4	100
7		Elective 1	4	100
8		Elective 2	4	100
9		Elective 3 (open)	4	100

Practical courses and Comprehensive Viva voce (Semester I and Semester II)

Sl. No	Code	SUBJECT	Credit	Marks
1		Bioanalytical Techniques Lab	2	100
2		Applied Bioinformatics Lab	2	100
3		Biotechnology and Biochemical engineering Lab	2	100
4		Bioprocess and Bioseparation Technology Lab	2	100
5		Seminar	1	100
6		Comprehensive viva voce	2	100
7		Project Preliminary	3	100
8		Project I	10	100
9		Project II	20	300

Elective Courses (Semester I and Semester II)

Sl.No	Code	SUBJECT*
1.		Bioprocess Plant Design
2.		Biomedical signal and Image processing
3.		Animal Biotechnology
4.		Advanced Immunology and Immunotechnology
5.		Synthetic Biology
6.		Cancer Biology
7.		Protein Structure and Engineering
8.		Biological Waste Treatment
9.		Food Process Engineering
10.		Tissue Engineering
11.		Nanobiotechnology
12.		Biomaterials
13.		Advanced Molecular Biology
14.		Computational Fluid Dynamics in Biology
15.		IPR and Biosafety
16.		Advanced BioMEMS
17.		Advanced Biomechanics
18.		Advanced Biomedical Instrumentation
19.		Biosensors, Transducers and Measurement Devices
20.		Prosthetics and Orthotics
21.		Metabolic Process and Engineering
22.		Systems Biology
23.		Biostatistics
24.		Advanced Genetic Engineering
25.		Molecular Therapeutics
26.		Bioentrepreneurship
27.		Pharmaceutical Biotechnology
28.		Process Control & Instrumentation
29.		Environmental Biotechnology

* Department will float any subject from the elective list as departmental electives or as open electives for a particular academic session.

** Students may choose any course (at least 40 hours or 12 weeks) from open learning sources (MOOCS or any other) or from the PG courses of any other department as Open Elective. Those courses must be available during that particular session. Besides, the approval of competent authority of NITA is applicable for the online courses.

Core Course 01: (1st Semester)

1. Name of the Subject: BIOANALYTICAL TECHNIQUES

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Bioanalytical Techniques		3	1	0	4	4	20	50	30

3. Course Objectives:

i. To provide the students an ability to understand the principles of instrumentation used in biotechnology research
ii. To impart the knowledge of different techniques and methods in biotechnology and biochemical engineering
iii. To improve the understanding of applications of techniques in the field of biotechnology and biochemical engineering

4. Course Content:

Module I: Spectroscopy Techniques: UV-Visible, Fluorescence, FTIR, NMR, ESR, Raman Spectroscopy, Mass Spectrometry (MALDI-TOF), LS-MS, ICP-MS, AAS, Circular Dichroism, XRD.

Module II: Biomedical Imaging techniques: MRI, X-ray, Scintigraphy, Angiography, Diagnostic instrument techniques, etc.

Module III: Microscopy: Optical, bright field, dark field, phase contrast, Fluorescence, Confocal laser scanning microscope, SEM, TEM, Atomic force microscope

Module IV: Flow cytometry, immunotechniques and radioactive techniques.

**- Demonstration of available instruments.*

5. Text/Reference:

a) *I. D. Campbell, Biological spectroscopy (Benjamin/Cummings Pub. Co, Menlo Park, Calif, 1984), Biophysical techniques series.*
b) *K. Wilson, J. M. Walker, Eds., Principles and techniques of biochemistry and molecular biology (Cambridge University Press, Cambridge, UK: New York, 7th ed., 2009).*
c) *R. F. Boyer, Biochemistry laboratory: modern theory and techniques (Prentice Hall, Boston, 2nd ed., 2012).*
d) *R. Katoch, Analytical techniques in biochemistry and molecular biology (Springer, New York, 2011).*
e) *D. L. Spector, R. D. Goldman, Eds., Basic methods in microscopy: protocols and concepts from cells: a laboratory manual (Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y, 2006).*
f) *R. F. Boyer, Modern experimental biochemistry (Benjamin Cummings, San Francisco, 3rd ed., 2000).*
g) *J. R. Lakowicz, Principles of fluorescence spectroscopy (Springer, New York, 2006; http://site.ebrary.com/id/10229235).*
h) *D. B. Williams, C. B. Carter, Transmission electron microscopy a textbook for materials science (Springer, New York, 2009; http://dx.doi.org/10.1007/978-0-387-76501-3).*
i) *R. M. Silverstein, Spectrometric identification of organic compounds (John Wiley & Sons, Hoboken, NJ, 7th ed., 2005). 12. D. Harvey, Modern analytical chemistry (McGraw-Hill, Boston, 2000).*

6. Course Outcomes:

No. of Course Outcome	Name of the course outcome
CO-1	Understand the basic principle of the equipment available and identify the suitable and appropriate experiments for their research
CO-2	Student would have gained sufficient knowledge about the assays and analyzing data
CO-3	Understand the principle concepts in using microscopy and spectroscopy techniques
CO-4	Overall, gaining an understanding of the biomolecules at molecular level that are used for their analysis.
CO-5	Understand how to quantify and assay for different biomolecules

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	3	1	-	-	3	2	-	3
CO-2	3	-	-	3	2	1	3	2
CO-3	2	1	-	2	1	1	2	1
CO-4	2	1	1	3	2	-	3	2
CO-5	2	1	1	2	1	2	2	1
Total	12	4	2	10	9	6	10	9
Average	2	1	1	3	2	2	3	2

Core Course 02: (1st Semester)

1. Name of the Subject: BIOTECHNOLOGY AND BIOCHEMICAL ENGINEERING PRINCIPLES

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Biotechnology and Biochemical engineering Principles		3	1	0	4	4	20	50	30

3. Course Objectives:

i. To review the basic microbiology, biochemistry and rDNA technology essential for analysis of a biological system.
ii. To provide students an overview of heat and mass transfer operations, flow of fluid, unit operations and unit processes.
iii. The course also contains a module covering fundamentals of several processes involved in biological systems.

4. Course Content:

Module I: Introduction to basic and applied microbiology, Kinetics of cell growth, Concept of microbial recombination and transformation, Restriction and DNA modifying enzymes, Cloning and expression vectors, Expression of recombinant in bacterial, yeast and mammalian systems; Biotransformations, Enzymes as biocatalysts; Enzyme kinetics.

Module II: Principle of fluid flow: Elements of fluid dynamics (viscosity, fluid flow regimes, typical applications of Newtonian laminar flow), Flow properties of fluid, Transportation of fluids, flow of particulate solids; Application of fluid flow principles in Biotechnology

Module III: Principle of heat and mass transfer: Mechanisms of heat and mass transfer, Conductive heat and mass transfer (Fourier and Fick laws, examples of steady state conductive heat and mass transfer process), Convective heat and mass transfer (Determination of heat and mass transfer coefficients in bioreactors, Application of dimensionless numbers in convective heat and mass transfer), Steady state interphase mass transfer, Unsteady state heat and mass transfer.

Module IV: Modes of bioreactor operation; Material and Energy balances (steady and unsteady state) in Bioprocesses; Importance of rheological properties of fermentation broth; Design of heat exchanger for bioprocessing, Pasteurization; Agitation and aeration in Bioprocess; Biological treatment of Wastewater

5. Texts/References:

a) *Steven C Chapra, Raymond P Canale. "Numerical Methods for Engineers", McGraw Hill, 6th Edition, 2010.*
b) *Pauline M. "Bioprocess Engineering Principles", Elsevier, 2nd Edition, 2013*
c) *DoranFox RW and McDonald AT, "Introduction to fluid mechanics", John Wiley & Sons. 6th edition, 2010.*
d) *McCabe WL, Smith JM and Harriot P, "Unit Operations of Chemical Engineering", McGraw Hill, 7th edition, 2005*
e) *Geankoplis, "Transport process and Unit Operations", PHI, 4th Ed., 2007.*

6. Course Outcomes:

No. of Course Outcome	Name of the course outcome
CO-1	Ability to apply basic principles of microbiology, biochemistry, and r-DNA in the field of biotechnology and biochemical engineering
CO-2	Ability to apply basic principles of heat and mass transfer in the field of biochemical engineering
CO-3	Ability to apply basic principles of fluid flow in the field of biochemical engineering
CO-4	Ability to solve basic numerical problems based on material and energy balance involved in the field of biochemical engineering

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	2	2	3	2	2	2	3	-
CO-2	2	1	3	2	3	2	3	-
CO-3	1	2	2	2	2	2	3	-
CO-4	2	2	3	2	3	3	3	3
Total	7	7	11	8	10	9	12	3
Average	1.75	1.75	2.75	2	2.5	2.25	3	3

Core Course 03: (1st Semester)

1. **Name of the Subject:** GENOMICS AND PROTEOMICS
2. **Credit Structure:**

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Genomics and Proteomics		3	1	0	4	4	20	50	30

3. **Course Objectives:**
   i. To provide an overview of genome organization, genome sequencing and their application in modern research.
   ii. To discuss the crucial concepts and techniques applied in gene regulation, gene transcription and translation of different organism.
   iii. The course will also discuss about the complexity of genome/ proteome organization, proteogenomics and transcriptomics.
4. **Course Content:**

Module I: Concept of structural genomics: Overview of Human genome organization, DNA sequencing strategies, DNA marker and mapping; RFLP, SNP, SSLP, STS mapping, Advance DNA sequencing techniques; Genome-wide association (GWA) analysis; Massively parallel Signature Sequencing (MPSS)

Module II: Functional Genomics: Introduction to DNA microarray; Designing and producing microarrays; types of microarrays; cDNA microarray technology; oligonucleotide arrays; Gene Expression analysis by cDNA and oligonucleotide arrays; Subtractive DNA library screening, Differential display.

Module III: Concept of transcriptomics: Concepts of forward and reverse genetics; Transcript Sequencing vs. Hybridization; Functional Genomics using RNAi; High throughput transcriptomic techniques – Comparative Genomic Hybridization (CGH); Serial Analysis of Gene Expression (SAGE)

Module IV: Advanced Proteomics: Over-View of strategies used for the identification and analysis of proteins; 1-D and 2-D Polyacrylamide Gel Electrophoresis (PAGE) of Proteins, Zymogram; western blotting, DIGE, iTRAQ, MRM techniques Mass-Spectrometry in Proteomics, analysis, functional and comparative Proteomics, protein microarray and applications.

5. **Text/Reference:**

a) *Terence A Brown., Genomes, 2nd edition; Oxford: Wiley-Liss; 2002. ISBN-10: 0-471-25046-5*
b) *Richard M. Twyman; 'Principles of Proteomics', Publisher: BIOS Scientific Publishers, ISBN: 978-0815344728*
c) *Matthiesen R, 'Mass Spectrometry Data Analysis in Proteomics'; Humana Press 2007;* ***ISBN:*** *978-1-58829-563-7*
d) *Introduction to Proteomics: Tools for the New Biology. Daniel C. Liebler, Humana Press Inc., 2002. ISBN-10: 0896039919*

6. **Course Outcomes:**

No. of course outcome	Name of the course outcome
CO-1	To understand the basic concepts genomics, transcriptomics and proteomics and its importance in modern research
CO-2	To learn and analyze the various techniques, tools and online resources used in genomics, transcriptomics and proteomics research.
CO-3	To acquire the knowledge of gene expression and its application in clinical and health sciences.
CO-4	To study the complex interaction between genomics and proteomics and their application in modern research.

7. **CO-PO Matrices & CO-PSO Mapping of courses:**

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	1	1	3	3	3	3	3	3
CO-2	1	1	2	2	3	2	2	3
CO-3	2	1	3	3	3	3	3	3
CO-4	-	1	3	2	2	3	2	2
Total	4	4	11	10	11	11	10	11
Average	1.3	1	2.75	2.5	2.75	2.75	2.5	2.75

Core Course 04: (1st Semester)

1. **Name of the Subject:** APPLIED BIOINFORMATICS
2. **Credit Structure:**

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Applied Bioinformatics		3	1	0	4	4	20	50	30

3. **Course Objectives:**
   i. To integrate fundamental biological concepts with information technologies to learn about the molecular and cellular systems.
   ii. Analyze and evaluate biological data to predict evolutionary relationship between the microbes, plants and mammals.
   iii. Implement computational methodologies in order to solve complex biological problems.
4. **Course Content:**

Module I: Biological databases: Protein and Nucleotide databases, Pairwise Sequence Alignment: Dynamic Programming, Local and Global Alignment, Functional Annotation, Multiple sequence alignment, algorithms and applications

Module II: Distance and Character based methods for phylogenetic tree construction: UPGMA, Neighbour joining, Ultrametric and Min-ultrametric trees, Parsimonous trees, Additive trees, statistical evaluation methods.

Module III: Molecular Docking principles and applications, Molecular dynamics simulations, Protein structure: visualization & prediction, Homology Modeling.

Module IV: Heuristic algorithms: Artificial Neural Networks and Hidden Markov Models and applications; Programming techniques in bioinformatics, Microarrays and Clustering techniques for microarray data analysis

5. **Text/Reference:**

a) *Arthur Lesk; Introduction to Bioinformatics, Oxford University Press, Second edition, 2002*
b) *David W. Mount; Bioinformatics: Sequence and Genome Analysis; CSHL Press; First edition, 2001*
c) *Jin Xiong; Essential Bioinformatics. Cambridge University Press, 1st edition 2006*
d) *Richard Durbin; Sean R. Eddy; Anders Krogh; Graeme Mitchison; Biological Sequence Analysis: Probabilistic Models of Proteins and Nucleic Acids, Cambridge University Press, 3rd edition, reprint 2008.*

6. **Course Outcomes:**

No. of course outcome	Name of the course outcome
CO-1	To comprehend the scope of Bioinformatics and the importance of biological database using online resources
CO-2	To acquire the contextual knowledge of exhaustive and heuristic algorithms used for sequence alignment.
CO-3	To study and evaluate the phylogenetic model for better interpretation of biological data for human welfare.
CO-4	To analyze the structure of genome and proteome using probabilistic model, online resources and testing the accuracy of predicted model.

7. **CO-PO Matrices & CO-PSO Mapping of courses**:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	1	2	3	3	2	3	2	3
CO-2	1	3	3	3	3	2	2	3
CO-3	1	3	3	3	3	3	2	2
CO-4	1	2	2	3	3	2	2	2
Total	4	10	11	12	11	10	8	10
Average	1	2.5	2.75	3	2.75	2.5	2	2.5

Practical Course#01: (1st Semester)

1. Name of the Subject: BIOANALYTICAL TECHNIQUES LABORATORY

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Bioanalytical Techniques Laboratory		0	0	2	3	2	-	80	20

3. Course Objectives:

i. To impart technical knowledge about the working principle and applications of different equipment related to biotechnology experiments.
ii. To enable the students to understand the principles of instrumentation.
iii. To impart the knowledge of different techniques and methods in biotechnology and biochemical engineering.

4. Course Content:

Exposure to the following instruments, sample preparation, data analysis and its interpretation

A) Microscopy: optical microscope, atomic force microscope, SEM, TEM;
B) Spectrophotometric techniques: UV-Visible, FTIR, Fluorescence; AAS
C) PCR and RT-PCR;
D) HPLC, GC;
E) Homogenizer; Centrifuge;
F) Sterilization units, Pumps and Bioreactor;
G) Biomedical instrumentations;

5. Text/Reference:

a) *Plummer Mu, David T. Plummer, Introduction to Practical Biochemistry, Tata McGraw-Hill Education, 1988*
b) *J. Sambrook, E.F. Fritsch, T. Maniatis. Molecular Cloning: A Laboratory Manual (Volume I, II & III), Cold Spring Harbor Laboratory press.*
c) *Skoog, D.A., Crouch, S.R., and Holler, F.J. "Principles of Instrumental Analysis", 6th edition, Brooks/Cole, USA, 2006.*
d) *Williams, D. and Fleming, I. "Spectroscopic Methods in Organic Chemistry", 6th edition, McGraw-Hill Higher Education, Maidenhead,UK, 2008.*
e) *Freifelder D., Willard and Merrit, Instrumental Methods and Analysis 5. Ewing GW, Instrumental Methods of Chemical analysis.*
f) *D. L. Spector, R. D. Goldman, Eds., Basic methods in microscopy: protocols and concepts from cells: a laboratory manual (Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y, 2006).*

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Able to explain principles of the performed experiments.
CO-2	Demonstrate proper operation of the equipment and instruments used in this course.
CO-3	To acquire the knowledge of standard of practice for safe handling of equipments.
CO-4	Able to solve their unknown problems and document the results in laboratory reports.
CO-5	Complete exams that require problem solving and creative thinking.

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	3	1	1	3	3	2	3	3
CO-2	2	-	-	3	3	3	3	3
CO-3	2	1	2	2	2	2	2	2
CO-4	2	-	2	3	2	3	3	2
CO-5	1	1	3	3	2	3	3	2
Total	10	3	8	14	12	13	14	12
Average	2	1	2	3	2	2.6	3	2

Practical Course 02: (1st Semester)

1. Name of the Subject: APPLIED BIOINFORMATICS LAB

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Applied Bioinformatics lab		0	0	2	3	2	-	80	20

3. Course Objectives:

i. To give practical exposure about basic online resources, tools and databases employed in bioinformatics.
ii. To develop bioinformatics programs for comparing & analyzing biological data to identify probable biological function.
iii. Able to learn different computational methodologies to retrieve the suitable information from large datasets of biological origin.

4. Course Content:

1. Knowledge of different biological database: Protein and gene sequence databases, Structure databases, Pathway Databases, Bibliographic database (PUBMED, MEDLINE)
2. Sequence retrieval from biological database,
3. Sequence similarity searching of nucleotide and protein sequences, Finding homologous sequences, Multiple sequence alignment, Dynamic programming method- local and global alignment
4. Gene prediction methods, Primer Design for PCR, restriction enzymes, resource for restriction enzyme (REBASE), similarity search, application of BioEdit,
5. Tools and libraries for software development (Biopython), Visualization tools (PyMol), Analysis of protein sequence using Expasy.
6. Predict the structure of protein Homology modelling, phylogentic tree construction.
7. Drug Receptor interaction, Molecular docking, Energy minimization of a molecule, CADD
8. Bioperl modules- Databases, sequence retrieval & alignment, restriction enzyme analysis, mutation studies.

5. Text/Reference:

a) *Andreas D. Baxevanis and B. F. Francis Ouellette. BIOINFORMATICS: A Practical Guide to the Analysis of Genes and Proteins. A JOHN WILEY & SONS, INC., PUBLICATION, 2001*
b) *Jin Xiong; Essential Bioinformatics. Cambridge University Press, 1st edition 2006.*
c) *David W. Mount; Bioinformatics: Sequence and Genome Analysis; CSHL Press; First edition, 2001*

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Able to demonstrate the basic knowledge of biological database and data mining though online resources
CO-2	Able to interpret the biological data and implementation in diagnostics, research, drug discovery and other biotechnological industries.
CO-3	Able to predict the evolutionary relationship using dynamic programming and machine learning algorithms
CO-4	Able to visualize the protein structure and it its folding mechanism by various online resources

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	1	-	-	3	2	3	3	2
CO-2	2	2	3	3	3	3	3	3
CO-3	3	-	2	3	3	3	3	3
CO-4	3	-	2	3	3	3	3	3
Total	9	2	7	12	11	12	12	11
Average	2.25	2	2.3	3	2.7	3	3	2.7

Sessional Course 01: (1st Semester)

1. Name of the Subject: SEMINAR

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Seminar		0	0	1	2	1	-	100	-

3. Course Objectives:

i. Student will able to point out and discuss about the current, real word scientific problems and social welfares.
ii. Student will able to improve their communication and presentation skill.

4. Course Content:

Oral presentation on contemporary topic related to Biotechnology and Biochemical engineering**.**

5. Text/Reference:

Journals, Articles and book chapters related to the topics. Students can also access various online portals and databases (like e-sodhsindhu, PUBMED).

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Able to present the contemporary research in a brief meaningful way.
CO-2	Able to improve the oral communication and presentation skills
CO-3	Able to develop persuasive speech and proper argumentative skills in the presence of experts and panel members

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	2	3	2	3	2	2	3	2
CO-2	3	3	1	3	2	1	3	2
CO-3	2	3	2	3	-	3	3	-
Total	7	9	5	9	4	6	9	4
Average	2.3	3	1.6	3	2	2	3	2

Theory (Core) Course 05: (2nd Semester)

1. Name of the Subject: BIOREACTOR DESIGN AND ANALYSIS

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Bioreactor Design and analysis		3	1	0	4	4	20	50	30

3. Course Objectives:

i. To provide students an in-depth knowledge of design, operation and optimization of bioreactors commonly used for preparation of biochemical products.
ii. The course focuses on different online, offline analytical methodologies required for optimal reactor performance.
iii. The course also includes advanced level design of different batch, continuous, and semi-batch reactors under ideal and non-ideal conditions along with an overview of scale-up.

4. Course Content:

Module I: On-line data analysis for measurement of important physico-chemical and biochemical parameters; Methods of on-line and off-line biomass estimation

Module II: Gas-liquid mass transfer in cellular systems, determination of oxygen transfer rates, mass transfer for freely rising or falling bodies, forced convection mass transfer, Overall kla estimation and power requirements for sparged and agitated vessels, mass transfer across free surfaces, other factors affecting kla, non-Newtonian fluids, Heat transfer correlations, thermal death kinetics of microorganisms, batch and continuous heat, sterilisation of liquid media, filter sterilisation of liquid media, Air. Design of sterilisation equipment batch and continuous.

Module III: Ideal bioreactors-batch, fed batch, continuous, cell recycle, plug flow reactor, two stage reactors, enzyme catalyzed reactions, other types of reactors- fluidized bed reactors, packed bed reactors, bubble column reactors, trickle bed reactors, non-ideality in bioreactors, Bioreactor strategies for maximising product formation; Case studies on high cell density cultivation and plasmid stabilization methods, Bioprocess design considerations for plant and animal cell cultures, Analysis of multiple interacting microbial populations

Module IV: Scaleup by geometry similitude, oxygen transfer, power correlations, mixing time

5. Text/Reference:

a) *Michael L. Shuler and Fikret Kargi, Bioprocess Engineering: Basic Concepts, Prentice Hall, 1992*
b) *James M. Lee, Biochemical Engineering, Prentice Hall, 1992*
c) *Pauline Doran, Bioprocess Engineering Principles, 2nd Edition, Academic Press 2012*
d) *James E. Bailey and David F. Ollis, Biochemical Engineering Fundamentals, McGraw Hill 1986.*
e) *S.Liu, Bioprocess Engineering: Kinetics, Biosystems, Sustainability, and Reactor Design, Elsevier, 2016*
f) *Octave Levenspiel, Chemical Reaction Engineering, Wiley 2016.*

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Understand different Online, offline analytical methodology required for optimal fermentation process and its importance.
CO-2	Design of heat transfer equipment, mass transfer equipment, and sterilization process
CO-3	Design of different batch, continuous, and semi-batch reactors under ideal conditions
CO-4	Design of different batch, continuous, and semi-batch reactors under non-ideal conditions and design of process
CO-5	Understand the aspects of scale-up.

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	2	1	2	3	1	1	3	-
CO-2	2	1	2	3	1	1	3	-
CO-3	2	1	2	3	1	1	3	-
CO-4	2	1	2	3	1	1	3	3
CO-5	2	1	2	3	1	1	2	1
Total	10	5	10	15	5	5	14	4
Average	2	1	2	3	1	1	2.8	2.0

Theory (Core) Course 06: (2nd Semester)

1. Name of the Subject: BIOSEPARATION TECHNOLOGY

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Bioseparation Technology		3	1	0	4	4	20	50	30

3. Course Objectives:

i. The objective of this course is to describe scientific and engineering principles utilized for separation and purification techniques which are used for large scale purification of biochemical products.
ii. The course also includes major unit operations involved in downstream processing in the field of biotechnology and biochemical engineering.
iii. The course focuses on designing and execution of a treatment train for recovery and purification of various commercially available biochemical products.

4. Course Content:

Module I: Biomass harvesting: sedimentation, flocculation, centrifugation and filtration; Cell disruption: sonication, bead mills, homogenizers, chemical lysis and enzymatic lysis

Module II: Precipitation (precipitation using organic solvent, salt, large scale precipitation, factors affecting precipitation), Extraction (chemistry of extraction, batch extraction, staged extraction, differential extraction, aqueous two-phase extraction, supercritical extraction) Electrophoresis, Crystallization, Drying, Lyophilization

Module III: Adsorption (chemistry of adsorption, adsorption in batch, CSTR and fixed-bed); Chromatography: General HPLC theory and terminology (principle, theoretical plates, retention time, retention factor, band broadening, resolution, yield and purity), HPLC techniques (affinity, ion exchange, size exclusion, reverse phase, hydrophobic interaction)

Module IV: Membrane based purification: microfiltration, ultrafiltration, diafiltration, reverse osmosis, dialysis, pervaporation. Product recovery trains for commercial enzymes, antibiotics, organic acids etc.

5. Text/Reference:

a) *Roger G Harrison et al "Bioseparation Science and Engineering" Oxford University Press, 2003*
b) *Belter PA and Cussler E, " Bioseparations", Wiley 1985*
c) *Christie J Geankoplis, "Transport processes and unit operations" Allyn& Bacon, 1978*

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Understand principles of separation and purification techniques used in biotechnology and biochemical engineering
CO-2	Understand scientific and engineering principles utilized for large scale purification of biochemical products
CO-3	Understand the major unit operations involved in downstream processing in the field of biotechnology and biochemical engineering.
CO-4	Design and optimize downstream operations in the field of biotechnology and biochemical engineering
CO-5	Understand the downstream processing of various commercially available biochemical products.

7. CO-PO Matrices:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	2	2	3	3	-	1	3	-
CO-2	2	1	2	3	-	2	3	-
CO-3	1	2	2	3	-	2	3	-
CO-4	2	1	3	3	3	3	3	3
CO-5	2	2	1	2	1	1	2	1
Total	7	8	11	14	4	9	14	4
Average	1.75	1.6	2.2	2.8	2.0	1.8	2.8	2.

Practical Course#03: (2nd Semester)

1. Name of the Subject: BIOTECHNOLOGY AND BIOCHEMICAL ENGINEERING LAB

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Biotechnology and Biochemical Engineering Lab		0	0	2	3	2	-	80	20

3. Course Objectives:

i. Develop skills of the students on advanced molecular biology techniques.
ii. To impart practical knowledge in cell culture techniques, growth of microbes, sterilization, on-line process monitoring.
iii. To develop the understanding of reaction kinetics in biochemical reactions and mass transfer in bioreactors.

4. Course Content:

1. Determination of microbial cell biomass by spectrophotometric, microscopic, gravimetric methods.
2. Estimation of various kinetic parameters (such as yield coefficient, specific growth rate, and maintenance) from bacterial growth curve.
3. To study the sterilization kinetics and determine the holding time
4. Determination of the Monod substrate saturation constant for microbial growth
5. To determine the Michaelis-Menten kinetic constants - maximum velocity of reaction (*Vm*) and saturation constant (*Km*) values of an enzyme catalysed reaction
6. Understanding of dissolved oxygen (DO) measurement system of a bioreactor and its calibration
7. Estimation of overall mass transfer coefficient (kLa) by dynamic gassing out technique
8. Estimation of mixing time in a batch reactor
9. Understanding of pH measurement system of a bioreactor and its calibration
10. Estimation of power input with gassing in a batch reactor
11. Isolation of plasmid DNA, genomic DNA; construction of recombinant DNA
12. Preparation of competent cells, transformation and expression of recombinants
13. Solubilisation and refolding of inclusion body proteins.
14. Study of Plasmid stability and competence in recombinant cell.

5. Text/Reference:

a) *Debabrata Das, Debayan Das, Biochemical Engineering: A Laboratory Manual, CRC press, 2020.*
b) *J. Sambrook, E.F. Fritsch, T. Maniatis. Molecular Cloning: A Laboratory Manual (Volume I, II & III), Cold Spring Harbor Laboratory press.*
c) *P. Gunasekharan, "Laboratory Manual in Microbiology", 1st ed., Newage International Publishers. 2005.*
d) *Peter F. Stanbury, Stephen J. Hall & A. Whitaker, "Principles of Fermentation Technology", Butterworth – Heinemann An Imprint of Elsevier India Pvt.Ltd., 2nd edition, 2005*

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Obtain hands-on experience in state of art laboratory techniques and documentation
CO-2	Understand to recent upstream developments in the fields of genetic engineering-gene cloning towards strain improvement
CO-3	Comprehend the state of the arts in the field of biochemical engineering specifically techniques to measure, calibrate and control bioprocess controlling parameters
CO-4	Understand the kinetic behaviour of microbial and enzymatic system through development of appropriate mathematical models
CO-5	Obtain hands-on experience in state of art laboratory techniques and documentation

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	2	3	1	1	2	1	2	1
CO-2	3	-	2	2	2	2	2	2
CO-3	3	1	2	2	1	2	2	2
CO-4	3	-	2	2	1	1	2	2
CO-5	11	4	7	7	6	6	8	7
Total	2.75	1	1.75	1.75	1.5	1.5	2	1.75
Average	2	3	1	1	2	1	2	1

Practical Course#04: (2nd Semester)

1. Name of the Subject: BIOPROCESS AND BIOSEPARATION LAB

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Bioprocess and Bioseparation Lab		0	0	2	3	2	-	80	20

3. Course Objectives:

i. The course provides a "hands-on" laboratory-based reinforcement of concepts covered in the field of biotechnology and biochemical engineering.
ii. The course is designed to provide practical training on various techniques involved in separation and purification of metabolites from microbial source.
iii. The course aims at preparation and aseptic handling of culture medium along with operation and optimization of process parameters in a bioreactor.

4. Course Content:

1. Sterilization, disinfection, safety in microbiological laboratory
2. Isolation of microorganisms, preparation of media for microbial growth
3. Determination of thermal death point and thermal death time of microorganisms
4. To study biotransformation using immobilized enzymes in a batch/ packed-bed/ fluidized bed reactor.
5. To compare kinetic parameters between free and immobilized enzyme systems in a batch reactor
6. Determination of intra-particle diffusion coefficient in adsorption operation
7. Preparation and characterization of immobilized enzymes
8. Extraction and purification of biomolecules from microbial sources to simulate industrial microbial processes.
9. Separation of proteins through SDS-PAGE, isoelectric focusing
10. Applications of membrane separation in large-scale purifications
11. Application of chromatographic methods in bioseparations.

5. Text/Reference:

a) *P. Gunasekharan, "Laboratory Manual in Microbiology", 1st ed., Newage International Publishers. 2005.*
b) *Peter F. Stanbury, Stephen J. Hall & A. Whitaker, "Principles of Fermentation Technology", Butterworth – Heinemann An Imprint of Elsevier India Pvt.Ltd., 2nd edition, 2005*

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Prepare independently proper culture medium for microbial growth and can handle them aseptically
CO-2	Comprehend various process variables and types of bioreactors used in industry
CO-3	Operate and optimize process parameters in a bioreactor for producing useful industrial products
CO-4	Proficiency in designing and conducting experiments involving gene manipulation.
CO-5	Understand various techniques involved in separation and purification of metabolites from microbial source.

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	3	2	3	3	2	2	3	2
CO-2	3	1	3	3	2	2	3	2
CO-3	2	1	2	2	2	3	3	2
CO-4	2	1	3	2	2	2	3	3
CO-5	2	2	1	2	2	2	2	1
Total	12	7	12	12	10	11	14	10
Average	2.4	1.4	2.4	2.4	2	2.2	2.8	2.0

Sessional Course#02: (2nd Semester)

1. **Name of the Subject:** PROJECT PRELIMINARY
2. **Credit Structure:**

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Project Preliminary		0	0	3	6	3	-	100	-

3. **Course Objectives:**
   i. Student will able to develop the higher cognitive abilities about the modern research and development about the selected field.
   ii. Apply their theoretical framework in the qualitative research.
4. **Course Content:**
   Familiarization with various techniques used in contemporary research in the field of biotechnology and biochemical engineering that will be useful in successful completion of their project work in the final year.
5. **Text/Reference:**
   Journals, Articles and book chapters related to the topics. Students can also access various online portals and databases (like e-sodhsindhu, NCBI).
6. **Course Outcomes:**

No. of course outcome	Name of the course outcome
CO-1	Able to conduct a systematic search of the relevant research literature from reputed journals.
CO-2	Able to gain knowledge of contemporary research, current development and novel methodologies in the field of biotechnology and biochemical engineering.
CO-3	Understand the significance of integrity and ethics in the field of research and publication.
CO-4	Able to prepare state of art report in the broad area of their M. Tech project

7. **CO-PO Matrices & CO-PSO Mapping of courses**:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	2	1	3	2	3	2	2	3
CO-2	1	-	3	1	-	2	1	-
CO-3	1	1	3	-	-	2	-	-
CO-4	3	3	3	-	3	2	-	3
Total	7	5	12	3	6	8	3	6
Average	1.75	1.66	3	1.5	3	2	1.5	3

Sessional Course#03: (2nd Semester)

15. Name of the Subject: COMPREHENSIVE VIVA VOCE

16. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Comprehensive Viva Voce		0	0	2	0	2	-	100	-

17. Course Objectives:

The objective of this course is to evaluate the theoretical knowledge of the students in the relevant field of Biotechnology and Biochemical engineering.

18. Course Content:

1st semester and 2nd Semester M. Tech Course curriculum.

5. Text/Reference

All books of M. Tech Course Curriculum

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Demonstrate in depth knowledge in the current program domain in front of experts and panel members.
CO-2	Demonstrate good communication skill and professional etiquettes
CO-3	Provide a platform to express their thoughts precisely and persuasively for future endeavor

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	-	1	3	2	-	1	2	-
CO-2	2	-	3	-	-	-	-	-
CO-3	-	1	2	2	-	1	2	1
Total	2	3	8	4	-	2	4	1
Average	2	1	2.6	2	-	1	2	1

Sessional Course #04: (3rd Semester)

1. **Name of the Subject:** PROJECT AND THESIS-1
2. **Credit Structure:**

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Project and Thesis-1		0	0	10	-	10	-	100	-

3. **Course Objectives:**
   i. To help the students to distinguish analogies between the theoretical concept and experimental work in a particular field.
   ii. To involve the students in integrated activities of reading, research and discussion around a selected field.
   iii. Create a collaborative environment that helps the student to establish healthy relationships among the colleagues.
4. **Course Content:**
   Literature survey and project related work**.**
5. **Text/Reference:**
   Journals, Articles and book chapters related to the topics. Students can also access various online portals and databases (like e-sodhsindhu, NCBI).
6. **Course Outcomes:**

No. of course outcome	Name of the course outcome
CO-1	Able to design the appropriate working protocol and plan the experiments.
CO-2	Capable of self-education and clearly understand the value of achieving perfection in the respective Project work.
CO-3	Able to work in multidisciplinary environments as a member and leader in a Project team
CO-4	Able to interpret, discuss and communicate scientific results in the oral and written form with clarity.

7. **CO-PO Matrices & CO-PSO Mapping of courses**:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	3	3	3	2	3	3	2	3
CO-2	3	3	3	1	-	1	1	-
CO-3	3	3	3	-	-	2	-	-
CO-4	3	3	2	-	3	2	-	3
Total	12	12	11	3	3	8	3	3
Average	3	2.75	3	3	3	2	3	3

Practical Course#07: (3rd Semester)

1. **Name of the Subject:** PROJECT AND THESIS-2
2. **Credit Structure:**

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Project and Thesis-2		0	0	20	-	20	-	300	-

3. **Course Objectives:**
   i. Able to understand the relevance of the problem for the chosen filed and gain deeper knowledge of the contemporary research.
   ii. Learn to write the scientific notes, technical reports, research article and review papers.
4. **Course Content:**
   Project related work, Preparation of M. Tech dissertation.
5. **Text/Reference:**
   Journals, Articles and book chapters related to the topics. Students can also access various online portals and databases (like e-sodhsindhu, NCBI).
6. **Course Outcomes:**

No. of course outcome	Name of the course outcome
CO-1	Able to acquire in depth knowledge and technical skills in their chosen field of research.
CO-2	Able to write with project report independently with proper data interpretation and formulate it in terms of journal publications and conference proceedings.
CO-3	Able to communicate and present their research work to the experts and panel members.
CO-4	Able to develop proficient research aptitude and technical skills to secure a position in the relevant field of biotechnology and biochemical engineering

7. **CO-PO Matrices & CO-PSO Mapping of courses**:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	3	3	3	2	3	3	2	3
CO-2	3	3	3	1	-	3	1	-
CO-3	3	3	3	-	-	3	-	-
CO-4	3	3	2	-	3	3	-	3
Total	12	12	11	3	3	12	3	3
Average	3	2.75	3	3	3	2.75	1.5	3

Elective courses#01

1. Name of the Subject: BIOPROCESS PLANT DESIGN

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Bioprocess Plant Design		3	1	0	4	4	20	50	30

3. Course Objectives:

i. To understand the fundamental concept of bioprocess plant design.
ii. To learn the process flow diagram, material & energy balance calculation method of design.
iii. Learn about the process of bioprocess plant design, such as, design, process design, plant design, design development stages.
iv. Develop the design objectives: new process development, new production capacity to meet growing sales, modification and addition to existing plants, setting design basis, generation of possible design concepts, economic evaluation, optimization and selection.
v. Apply it for process intensification. Use different softwares for process development, design purpose.

4. Course Content:

Module–1: Introduction; general design information, mass and energy, flow sheeting, piping and instrumentation, difference between Block Flow Diagrams (BFDs), Process Flow Diagrams (PFDs), Piping and Instruments (PIDs) or P & I Diagram, major factors necessary in the selection of plant site, advantage of plant layout.

Module-2: Materials of construction for bioprocess plants, mechanical design of process equipment, vessels for biotechnology applications, design consideration for maintaining sterility of process streams and processing equipment.

Module-3: Selection and specification of equipment for handling fluids and solids, selection specification and design of heat and mass transfer equipment used in bioprocess industries, utilities for biotechnology production plants.

Module–4: Process economics, bioprocess validation, safety considerations, case studies. Learn to handle different types of modelling & simulation and optimization software to bioprocess plant design.

5. Text/ References

a) *Peter MS, Timmerhaus KD, "Plant design and economics for chemical Engineering" McGraw Hill International edition, 4th edition, 1991.*
b) *Gavin Towler, Ray Sinnot, "Chemical Engineering Design, Principles, Practice & economics of Plant & Process Design"' ELSEVIER BH Publication.*
c) *Harry Silla, "Chemical Process Engineering, Design & Economics", Marcel Dekker, INC.*
d) *Demetri Petrides, "Bioprocess design"*
e) *Frank Peter Helmus, "Process plant design" Wiley*
f) *J. R. Backhurst, J. H. Harker, Process plant design" Heinemann Educational Books Ltd.*
g) *Pauline M. Doran, "Bioprocess engineering principle" Elseiver, 2nd edition*
h) *B.C. Bhattacharyya, "Introduction to chemical equipment design" CBS Publishers and Distributors.*
i) *Sean Moran, "An applied guide to process and plant design" 2nd edition.*

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Understand the fundamental concept of bioprocess plant design.
CO-2	Learn the process flow diagram, material & energy balance, instrumentation & control, optimization, plant safety, calculation method of design.
CO-3	Learn about the process of bioprocess plant design: equipment, process, product & entire plant design, design development stages.
CO-4	Develop the design objectives: new process development, new production capacity to meet growing sales, modification and addition to existing plants, setting design basis, generation of possible design concepts, economic evaluation, optimization and selection.
CO-5	Apply it for process intensification. Use different software's, modeling, simulation and optimization technique for process development, design energy saving and cost minimization purpose.

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	3	3	3	3	3	1	3	3
CO-2	3	3	3	3	3	1	3	3
CO-3	3	3	3	3	2	2	2	2
CO-4	3	3	3	3	3	2	3	2
CO-5	3	3	3	3	3	1	3	2
Total	15	15	15	15	14	7	14	12
Average	3	3	3	3	2.8	1.4	3	2.5

Elective courses#02

1. **Name of the Subject:** BIOMEDICAL SIGNAL AND IMAGE PROCESSING
2. **Credit Structure:**

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Biomedical Signal and Image Processing		3	1	0	4	4	20	50	30

3. **Course Objectives:**
   I. This course presents the fundamentals of digital signal processing with particular emphasis on problems in biomedical research and clinical medicine
   II. To Understand the biomedical signal and image processing methods and skills for processing/analysis of biomedical data obtained from various modalities (EEG, ECG, MRS spectroscopy, MRI, CT, nuclear imaging).
4. **Course Content:**

Module I: Data Acquisition: Sampling in time, aliasing, interpolation, and quantization, time-averaging, ensemble averaging cross-correlation function. Discrete time systems and signals; Different transform and techniques for filter designs.

Module II: Inverse filtering: Deconvolution and equalization techniques, Weiner, Linear prediction etc., Signal reconstruction; Time frequency Analysis - STFT, WT, DSP hardware - Design methodologies, and overview of programming application; Filter implementation: topology, scaling, coefficient quantization, signal quantization, sensitivity analysis**.**

Module III: Digital image fundamentals; Matrix theory in image processing; Image transforms: 2D-DFT, FFT, Walsh, Hadamard, Haar, DCT and Wavelet transforms; Image enhancement techniques; colour image processing techniques; image compression

Module IV: Image segmentation techniques and 3D image reconstruction methods

5. **Texts/References:**
   a) *Biosignal and Medical Image Processing By John L. Semmlow ,Benjamin Griffel.*
   b) *Biomedical Signal and Image Processing By Kayvan Najarian Robert Splinter*
6. **Course Outcomes:**

No. of course outcome	Name of the course outcome
CO-1	Students will get the clear domain knowledge about the various analysis of various bio-signals.
CO-2	Study the signal filtering techniques, signal restoration and different hardware designing procedures
CO-3	Students will get the clear domain knowledge the image fundamentals and image transforms
CO-4	Study the image enhancement techniques, Image restoration and compression, segmentation procedures
CO-5	Student will be able to understand the various diagnostic applications of the medical imaging techniques

7. **CO-PO Matrices & CO-PSO mapping of courses:**

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	1	1	3	2	3	3	3	3
CO-2	1	1	2	2	2	2	2	3
CO-3	2	1	3	2	3	3	3	3
CO-4	1	1	2	2	1	3	2	2
CO-5	-	1	2	2	3	1	-	1
Total	5	5	12	10	12	12	10	12
Average	1	1	2.4	2	2.4	2.4	2	2.4

Elective courses#03

1. Name of the Subject: ANIMAL BIOTECHNOLOGY

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Animal Biotechnology		3	1	0	4	4	20	50	30

3. Course Objectives:

I. Understanding the fundamental principles of biotechnology and its application in agriculture, veterinary sciences, medical sciences, industry and environment

II. Pursuing research related to animal cell culture at national and international level.

4. Course Content:

Module I: Different tissue culture techniques; Types of primary culture; Chicken embryo fibroblast culture; Chicken liver and kidney culture; Secondary culture; Trypsinization; Cell separation; Continuous cell lines; Suspension culture; Organ culture etc.; Behavior of cells in culture conditions: division, growth pattern, metabolism of estimation of cell number; Development of cell lines; Characterization and maintenance of cell lines, stem cells; Cryopreservation; Common cell culture contaminants.

Module II: Cell cloning and selection; Transfection and transformation of cells; Transfection methods - Ca phosphate precipitation, DEAE-Dextran mediated transfection, lipofection, fusion with bacterial protoplasts, electroporation; targeted gene transfer- gene disruption and gene replacement;

Module III: Scale-up: Cell culture reactors; Scale-up in suspension; Scale and complexity; Mixing and aeration; Rotating chambers; Perfused suspension cultures; Fluidized bed reactors for suspension culture; Scale-up in monolayers; Multi-surface propagators; Multi-array disks, spirals and tubes; Roller culture; Microcarriers; Perfused monolayer cultures; Membrane perfusion; Hollow fiber perfusion; Matrix perfusion; Microencapsulation; Growth monitoring

Module IV: Cell culture products: viral vaccines, interferons, recombinant proteins, hybrid antibodies; in-vitro fertilization in humans, embryo transfer in cattle, applications of embryo transfer technology; Production of transgenic animals with special reference to transgenic mice, cow and sheep; Application of animal cell culture for in vitro testing of drugs; Testing of toxicity of environmental pollutants in cell culture; identification and transfer of genes influencing milk quality and disease resistance; production of pharmaceuticals

4. Text/Reference:

a) Culture of animal Cells, A manual of Animal Cells, R.Ian Freshney

b) Principles of Gene Manipulation; S. B. Primrose, R. Twyman, R.W. Old; Wiley-Blackwell; 6th Edition.

5. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Describe the limitations and challenges facing the animal industries and disciplines
CO-2	Describe the various biotechnologies available to the animal related fields
CO-3	Evaluate and discuss public and ethical concerns over the use of animal biotechnology
CO-4	Locate and critically evaluate scientific literature and experimental studies relating to animal biotechnology and be able to effectively communicate the findings in oral and written form.

7. CO-PO Matrices & CO-PSO mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	2	1	1	2	1	1	3	2
CO-2	1	1	1	1	1	1	2	2
CO-3	1	1	1	2	1	1	3	2
CO-4	2	1	2	1	2	2	2	2
Total	4	4	5	6	5	5	10	8
Average	1.5	1	1.25	1.5	1.25	1.25	2.5	2

Elective courses#04

1. Name of the Subject: ADVANCED IMMUNOLOGY AND IMMUNOTECHNOLOGY

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Advanced Immunology and Immunotechnology		3	1	0	4	4	20	50	30

3. Course Objectives:

I. This course will teach the biology of the Immune system and apply this knowledge to an understanding of human disease and basic immunological research

II. The course introduces students to a wide range of topics in immunology starting from cells of immune system, innate and adaptive immune systems, humoral immunity, antibody structure and function, basic immunological techniques, autoimmunity, hypersensitivity and vaccine production.

4. Course Content:

Module I: Immunology- fundamental concepts and anatomy of the immune system, Components of innate and acquired immunity; Phagocytosis; Complement and Inflammatory responses; Haematopoesis; Organs and cells of the immune system-primary and secondary lymphoid organs; Lymphatic system; Lymphocyte circulation; Lymphocyte homing; Mucosal and Cutaneous associated Lymphoid tissue.(MALT & CALT); Mucosal Immunity; Antigens - immunogens, haptens; Major Histocompatibility Complex - MHC genes, MHC and immune responsiveness and disease susceptibility, HLA typing.

Module II: Immune responses generated by B and T lymphocytes, Immunoglobulins-basic structure, classes and subclasses of immunoglobulins, antigenic determinants; Multigene organization of immunoglobulin genes; B-cell receptor; Immunoglobulin superfamily; Principles of cell signaling; Immunological basis of self –non-self discrimination; Kinetics of immune response, memory; B cell maturation, activation and differentiation; Generation of antibody diversity; T-cell maturation, activation and differentiation and T-cell receptors; Functional T Cell Subsets; Cell-mediated immune responses, ADCC; Cytokines-properties, receptors and therapeutic uses; Antigen processing and presentation- endogenous antigens, exogenous antigens, non-peptide bacterial antigens and super-antigens; Cell-cell co-operation, Hapten-carrier system

Module III: Antigen-antibody interactions: Precipitation, agglutination and complement mediated immune reactions; Advanced immunological techniques - RIA, ELISA, Western blotting, ELISPOT assay, immunofluorescence, flow cytometry and immunoelectron microscopy; Surface plasmon resonance, Biosenor assays for assessing ligand –receptor interaction, CMI techniques- lymphoproliferation assay, Mixed lymphocyte reaction,

Module IV: Vaccinology: 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.

Module V: 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 immune-deficiencies, Acquired or secondary immune-deficiencies.

5. Text/Reference:

a) Kuby Immunology, by Judy Owen, Jenni Punt, Sharon Stranford, Patricia Jones;

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Able to understand the various mechanisms that regulate immune responses and maintain the tolerance
CO-2	Able to understand the adverse effect of immune system including Allergy, hypersensitivity and autoimmunity
CO-3	Able to apply basic techniques for identifying antigen and antibody interactions.
CO-4	Able to explain the stages of transplantation of various transplant procedures
CO-5	Able to elucidate the reasons for immunization and aware of different vaccination

7. CO-PO Matrices & CO-PSO mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	1	1	2	2	3	3	3	3
CO-2	1	1	1	2	2	2	2	3
CO-3	2	-	3	2	3	3	3	3
CO-4	1	1	2	3	1	3	2	2
CO-5	-	-	2	2	3	1	3	1
Total	5	3	10	11	12	12	13	12
Average	1	**0.6**	2	2.2	2.4	2.4	2.6	2.4

Elective courses#05

1. Name of the Subject: SYNTHETIC BIOLOGY

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Synthetic Biology		3	1	0	4	4	20	50	30

3. Course Objective:

i. To understand how synthetic biology alters the properties of the cell or the organism.
ii. To apply a scientific approach to the planning, execution, reporting and interpretation of advanced projects with the aim at creating replicating systems with new properties that can be regulated, and to critically analyse the results and generate testable hypotheses from these experiments.

4. Course Content:

Module-I: History, definition, Concepts, standardization of biological parts and hierarchical abstraction, Sequencing and fabrication, multiple conditions for accurate modeling and computer-aided-design (CAD), laboratory highlighting BioBrick cloning and chromoprotein reporters as a methodology in synthetic biology.

Module-II: Modeling: Modular protein assembly, modeling of all biomolecular interactions in transcription, translation, regulation and induction of gene regulatory networks; molecular motifs in a bigger network with upstream and downstream components in living cell.

Module-III: Example of applications: Biological computers, Biosensors, Cell transformation, Designed proteins, Industrial enzymes, Information storage, Materials production, Reduced amino-acid libraries, Space exploration, Synthetic genetic pathways, Synthetic life, Synthetic amino acids, Synthetic nucleotides; Bioethics and security.

4. Text/Reference:

a) Liljeruhm, Josefine; Gullberg, Erik; Forster, Anthony C.Synthetic biology: a lab manual
b) Journal: Synthetic biology, Nature Publisher

5. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	The ability to understand the various definitions of synthetic biology
CO-2	An understanding of the context of synthetic biology with closely related field such as metabolic engineering and genetic engineering
CO-3	An understanding of the issues and relationships between 'top down' and 'bottom up' approach of synthetic biology
CO-4	An appreciation on how the synthetic biology might impact on aspects of interest to mankind internationally

6. CO-PO Matrices & CO-PSO mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	1	2	2	3	2	2	2	2
CO-2	1	2	2	3	3	2	2	2
CO-3	1	2	2	3	1	2	2	2
CO-4	1	2	2	3	3	2	2	2
Total	4	8	8	12	9	8	8	8
Average	1	2	2	3	2.5	2	2	2

Elective courses#06

1. Name of the Subject: CANCER BIOLOGY

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Cancer Biology		3	1	0	4	4	20	50	30

3. Course Objectives:

I. To understand the about the underlying principle of cell cycle n which alters the properties of the cell or the organism.
II. To impart the knowledge of advance research in the field of cancer biology and their early diagnosis and treatment.

4. Course Content:

Module I: Cancer Biology Overview, Types of Cancer, Causes for cancer.
Module II: Oncogenes and Tumor suppressors, Cell Cycle and Regulation, Cell Differentiation, Cell Death Pathways (Apoptosis, Autophagy), Necrosis, Cell Senescence, Cell Adhesion and Motility.
Module III: Cancer Epigenetics and sRNAs, Cancer Genome instability, Tumor Immunity, Growth Signaling pathways, Tumor angiogenesis, Cancer Stem Cell, Diagnosis, prognosis and treatment of cancer
Module IV: Very recent research updates on basic cancer research and drug development against cancer

5. Text/Reference:

a) *Molecular Biology of the Cell by Bruce Alberts, Latest Version/Edition*
b) *Various journals of international society*

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	The ability to understand the various definitions of cancer biology
CO-2	An understanding of the importance of cancer biology in societal aspects.
CO-3	An understanding of the issues and relationships between 'top down' and 'bottom up' approach of cancer progression and its control
CO-4	An overview of therapeutic aspect of cancer and its scope for future

7. **CO-PO Matrices & CO-PSO mapping of courses:**

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	3	3	3	3	3	2	2	2
CO-2	3	3	3	3	3	2	2	2
CO-3	3	3	3	3	3	1	2	2
CO-4	-	-	3	-	2	3	2	2
Total	9	9	12	9	11	8	8	8
Average	3	3	3	3	2.75	2	2	2

Elective courses#07

1. Name of the Subject: PROTEIN STRUCTURE AND ENGINEERING

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Protein Structure and Engineering		3	1	0	4	4	20	50	30

3. Course Objectives:

I. To provide knowledge of basic structure of protein and their folding.
II. Inculcate the importance of protein structure and folding in modern research

4. Course Content:

Module-I: Introduction to protein structure: Protein structural families: Basic structural principles: amino acids and their conformational accessibilities, Ramachandran Plot; Motifs of protein structures and their packing; Schematic and topology diagrams; Families of protein structures: alpha, alpha/beta, beta, small etc.

Module-II: Protein folding and assembly: Protein folding pathways in prokaryotes and eukaryotes; Single and multiple folding pathways; Protein folding of single domain and multi-domain proteins; Inclusion bodies and recovery of active proteins; Osmolyte assisted protein folding; Structure of chaperones and role of chaperones in protein folding.

Module-III: Protein engineering Strategies: Random and site directed mutagenesis; Various PCR based strategies; Role of low-fidelity enzymes in protein engineering; Gene shuffling and Directed evolution of proteins; Protein backbone changes; Antibody engineering; All topics will deal with case studies.

Module-IV: Prediction and design of protein structures Similar structure and function of homologous proteins; Role of multiple alignment; Homology and ab-initio method for protein structure prediction; Phage display systems; Structure based drug design and case studies, Rational protein design, Specific examples of enzyme engineering such as Tryesyl t RNAsynthetase, Dihydrofolate reductase, Subtilisin.

5. Text/Reference Book

1. Protein Structure and Protein Engineering, Winnacker Huber, Publisher: Springer, ISBN: 9783642741753, 3642741754, Edition: 2013

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	To acquire the fundamental knowledge of protein structure, protein family. domain and their interaction at cellular level.
CO-2	To learn the advanced techniques and tools for protein analysis useful for modern research
CO-3	To understand the protein folding mechanism, protein-protein interaction and protein stability
CO-4	To design the bioactive lead molecule from given protein sequence beneficial for human health.

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	3	2	1	-	-	2	3	2
CO-2	3	2	2	-	2	2	3	-
CO-3	2	3	3	3	2	2	3	2
CO-4	3	3	3	2	2	2	2	2
Total	13	13	12	8	6	8	14	6
Average	2.6	2.6	2.4	1.6	2	2	2.8	2

Elective courses#08

1. Name of the Subject: BIOLOGICAL WASTE TREATMENT

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Biological Waste Treatment		3	1	0	4	4	20	50	30

3. Course Objectives:

I. To provide technical knowledge about biological wastewater treatment
II. To provide students an ability to design effluent treatment plant
III. To provide students an ability to understand application of biotechnology and biochemical engineering in the field of waste treatment

4. Course Content:

Module I: Characterization of waste, waste disposal norms and regulations, stoichiomentry and bacterial energetics of biological treatment, microbial kinetics, reactor types (suspended growth reactors, attached growth reactors)

Module II: Introduction to aerobic suspended growth biological treatment, activated sludge treatment, characteristics of activated sludge, process configurations, aeration systems, bulking and other sludge settling problems, analysis and design of activated sludge, analysis and design of settlers

Module III:

Introduction to aerobic attached growth biological treatment systems, trickling filter, oxygen transfer and utilization, rotating biological contactors.

Module IV:

Biological nutrient removal: microbiology, process description and environmental factors for nitrification, denitrification and phosphorous removal

Module V: Introduction to anaerobic process, anaerobic suspended growth processes, anaerobic sludge blanket process, upflow attached growth processes, downflow attached growth processes

Module VI: Advanced wastewater treatment (depth filtration, surface filtration, adsorption, gas stripping, ion exchange), Treatment and disposal of sludge, biological means for stabilization and disposal of solid wastes, Treatment of hazardous and toxic wastes.

5. Text/Reference:

a) *Wastewater Engineering: Treatment and Reuse by Metcalf and Eddy*
b) *Environmental Biotechnology: Principles and applications by Bruce E Rittmann and Perry L McCarty*

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Ability to apply engineering skills for biological wastewater treatment
CO-2	Ability to understand the various types of bioreactors used in wastewater treatment
CO-3	Ability to understand unit operations related to biological wastewater treatment
CO-4	Ability to understand the role of microbes in wastewater treatment

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	2	3	2	2	3	1	2	2
CO-2	3	2	3	1	2	2	2	1
CO-3	2	2	2	2	3	2	3	2
CO-4	2	3	2	3	2	3	3	2
Total	9	10	9	8	10	8	10	7
Average	2.25	2.5	2.25	2	2.5	2	2.5	1.75

Elective courses#09

1. Name of the Subject: FOOD PROCESS ENGINEERING

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Food Process Engineering		4	0	0	4	4	20	50	30

3. Course Objectives:

I. To provide technical knowledge about food processing
II. To provide students an ability to design processed food with increased shelf life.
III. To provide students an ability to understand application of biotechnology and biochemical engineering in the field of food preservation and food processing

4. Course Content:

Module I: Chemical constituents of foods, their properties and functions; chemical/biochemical reactions in storage/spoilage/ handling of foods; food safety, quality control and certifications.

Module II: Preservation of food by thermal processing (factors affecting thermal resistance of microorganisms, spores and enzymes, 12D concept and thermal process calculations, optimization of thermal process with respect to quality, thermal processing in hermetically sealed containers and in bulk before packaging)

Module III: Other food preservation technologies (refrigeration/chilling/freezing, dehydration, food additives, CA-MA storage).

Module IV: Non-thermal processing (irradiation, high pressure processing, pulsed electric field)

Module V: Processing involved in following sectors: cereals, oil seeds, fruits and vegetables, fish, meat and poultry.

Module VI: Processing involved in following sectors: dairy, beverages, spices and herbs, confectioneries

5. Text/Reference:

a) *William C. Frazier, Dennis C. Westhoff, N.M. Vanitha, " Food Microbiology"*
b) *Romeo T. Toledo, "Fundamentals of Food Process Engineering"*
c) *H.K. Chopra, P.S. Panesar., "Food Chemistry"*
d) *P.S. Panesar, H.K. Sharma, B.C. Sarkar, "Bio-processing of foods"*
e) *R. L. Henricksons, "Meat, Poultry and Sea Food Technology"*
f) *N. L. Kent, "Technology of Cereals"*
g) *GiridhariLal, "Preservation of Fruits & Vegetables"*
h) *Prescott & Dunn, "Industrial Microbiology"*

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Ability to understand the component and nutritional value of food
CO-2	Ability to understand the thermal and non-thermal food preservation technologies
CO-3	Ability to understand the processing involved in various food sectors
CO-4	Ability to understand the importance of food safety and regulations

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	2	3	2	2	3	1	2	3
CO-2	2	2	3	1	2	2	2	1
CO-3	3	3	2	2	2	2	2	2
CO-4	2	3	3	2	2	3	3	2
Total	9	11	10	7	9	8	9	8
Average	2.25	2.75	2.5	1.75	2.25	2	2.25	2

Elective courses#10

1. Name of the Subject: TISSUE ENGINEERING

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Tissue Engineering		3	1	0	4	4	20	50	30

3. Course Objectives:

I. Provide knowledge about cell culture, cell signaling and growth factors
II. Inculcate the importance of characterization in cell culture for the identification
III. Impart technical skills in tissue implants and tissue engineering

4. Course Content:

Module I: Introduction to tissue engineering, Cells as therapeutic Agents with examples, Cell numbers and growth rates, Tissue organization, Tissue Components, Tissue types, Functional subunits. Tissue Dynamics, Dynamic states of tissues, Homeostasis in highly prolific tissues and Tissue repair. Angiogenesis.

Module II: Cellular fate processes, Cell differentiation, Cell migration - underlying biochemical process, Cell division - mitotic cell cycle, Cell death - biological description of apoptosis. Coordination of cellular fate processes - soluble signals, types of growth factors and chemokines, sending and receiving a signal, processing a signal, integrated responses, soluble growth factor receptors, Malfunctions in soluble signaling.

Module III: 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. 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.

Module IV: Biomaterials in tissue engineering - biodegradable polymers and polymer scaffold processing, Growth factor delivery, Stem cells, Gene therapy, Bioreactors for Tissue Engineering, In vivo cell & tissue engineering case studies: Artificial skin, Artificial blood vessels, In vivo cell & tissue engineering case studies: Artificial pancreas, Artificial liver, In vivo cell & tissue engineering case studies: Regeneration of bone, muscle, In vivo cell & tissue engineering case studies: Nerve regeneration.

5. Text/Reference:

a) *"Tissue Engineering", Bernhard O. Palsson, Sangeeta N. Bhatia, Pearson Prentice Hall Bioengineering.*
b) *"Nanotechnology and Tissue engineering - The Scaffold", Cato T. Laurencin, Lakshmi S. Nair, CRC Press.*

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Understand the different types of biomaterials that can be used in tissue engineering applications.
CO-2	Acquire knowledge on complex interaction between biomaterials, cells and signals in biological system.
CO-3	Learn the principles techniques skills and modern engineering tools used in tissue culture and regeneration.
CO-4	Develop student's ability to identify, formulate and adopt engineering solution to unmet biological needs.
CO-5	Able to understand broadly the key topics in tissue engineering.

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	3	2	-	1	1	1	3	3
CO-2	3	-	1	1	-	2	3	1
CO-3	3	-	1	-	1	2	2	2
CO-4	2	1	1	2	2	-	1	3
CO-5	2	2	2	1	1	1	2	2
Total	13	5	5	5	5	6	11	11
Average	3	2	1	1	1	2	2	2

Elective courses#11

1. Name of the Subject: NANOBIOTECHNOLOGY

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Nanobiotechnology		3	1	0	4	4	20	50	30

3. Course Objectives:

I. To introduce the concepts and fundamentals of nanotechnology.
II. To understand the synthesis and characterization of nanomaterials and their application in biotechnology fields.
III. To identify the risk assessments involved nanomaterials in biological application and the impact on environment

4. Course Content:

Module I: Basics of biology - cell, organelles and nucleic acids as genetic material, Biomacromolecules - Self assembly of proteins, oligonucleotides, amphipathic lipids. Organic & inorganic templates in biological systems (Bone mineralization, silicate deposits). Nanomaterial in biotechnology - nanoparticles, quantum dots, nanotubes and nanowires etc.

Module II: Development of nanobiotechnology - timelines and progress, overview, Biogenic nanoparticles, Stealth nanoparticles, Virosomes and virus-like nanoparticles for gene delivery, Stimuli responsive 'smart' nanosystems. Biosensors- different classes; molecular recognition elements, transducing elements, Applications of molecular recognition elements in nanosensing of different analytes.

Module III: Application of various transducing elements as part of nanobiosensors, Miniaturized devices in nanobiotechnology - types and applications, lab on a chip concept, Biological nanoparticles production - plants and microbial. Targeted nano delivery systems – The Trojan horse concept (Passive targeting, Active targeting, External triggers, Internal triggers),

Module IV: Nanobiotechnological applications in health and disease – infectious, genetic and chronic, Stem cells & Nanotechnology – Stimulating tissue regeneration (Importance of nanogeometry, nanochemistry & nanomechanics), Capture-based, Cell-based & Tissue based sensors, Nanoparticles for imaging, Nanobiotechnological applications in Environment and food - detection and mitigation.

5. Text/Reference:

a) *Nanobiotechnology: Concepts, Applications and Perspectives (2004), Christof M.Niemeyer (Editor), Chad A. Mirkin (Editor), Wiley VCH.*
b) *Nanobiotechnology - II more concepts and applications. (2007) - Chad A Mirkin and Christof M. Niemeyer (Eds), Wiley VCH.*
c) *Nanotechnology in Biology and Medicine: Methods, Devices, and Applications by Tuan Vo-Dinh, CRC Press.*
d) *An Introduction to Materials in Medicine. Edited by: Buddy D. Ratner, Allan S. Hoffman, Frederick J. Schoen and Jack E. Lemons, Academic Press, 2013.*

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Able to correlate the impact of nanotechnology and nanoscience in a global, economic, environmental, and societal context.
CO-2	Accquire a working knowledge in nanotechnology techniques (synthesis, fabrication, characterization) and acquire the ability to use them to solve problems in bioengineering, biomedicine and agricultural/environmental issues.
CO-3	Learn the principles governing the effect of size on material properties at the nanoscale, and perform quantitative analysis.
CO-4	Learn the wide range of applications of nanotechnology and its interdisciplinary aspect.
CO-5	Able to identify career paths at the interface of nanotechnology, biology, environmental and agricultural engineering and medicine.

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	3	2	2	1	1	1	3	3
CO-2	3	1	1	1	-	1	2	1
CO-3	3	-	-	1	1	-	2	2
CO-4	2	1	1	2	2	2	1	3
CO-5	3	2	3	-	2	2	3	3
Total	14	6	7	5	6	6	11	12
Average	3	2	2	1	2	2	2	2

Elective courses#12

1. Name of the Subject: BIOMATERIALS

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Biomaterials		3	1	0	4	4	20	50	30

3. Course Objectives:

I. To introduce the concepts of various classes of biomaterials on the basis of structure and function.
II. To understand the basic principle of various analytical methods to characterize bulk and surface properties of biomaterials.
III. To provide the concept of molecular and cellular events that follow exposure of materials to bodily fluids and to contact with various tissues of the human body

4. Course Content:

Module 1: Introduction to Biomaterials - Historical background and performance of biomaterials, The structure of solids - Atomic bonding and crystal structure of metals and ceramics, Long chain polymers and types of polymerization - Composite materials

Module 2: Characterization of Materials - Basics on physical, chemical and mechanical properties of materials, Biological Materials and Their Properties - The extracellular matrix and composition of hard and soft tissues, proteins (collagen & elastin), polysaccharides, and minerals (hydroxyapatite) - Structure and properties of mineralized tissue (bone and teeth), cartilage, tendons, ligaments and cardiovascular tissues

Module 3: Metallic Implant Materials: - Stainless steels, Co-based alloys, Ti & Ti alloys and dental metals - Corrosion of metallic implants, Ceramic Implant Materials- Aluminum oxides, calcium phosphates, glass-ceramics and carbons - Static and dynamic fatigues of ceramics. Polymeric Implant Materials - Effect of structure and temperature on properties - Deterioration of polymers 8. Composite Implant Materials - Structure and mechanics of composites - Application of composite biomaterials: dental filling composites, porous implants, fibrous and particulate composites in orthopaedic implants

Module 4: Tissue Response to Implants- Normal wound healing process - Inflammation - Biocompatibility and hemocompatibility - Body response to implants – Carcinogenecity, Application of Biomaterials for Soft and Hard Tissue Replacement - Vascular and heart valve implants - Artificial organs: artificial hearts, cardiac pacemakers and artificial kidney dialysis membrane - Commercialization of Implants - Regulations and regulatory testing - The ethics of biomaterials and implants

5. Text/Reference:

a) *Biomaterials Science: An introduction to materials in Medicine. Buddy D. Ratner et al. 3rd edition, 2012.*
b) *Biomaterials: The Intersection of Biology and Materials Science - Temenoff and Mikos (Pearson Prentice Hall; ISBN 0-13-009710-1), 1st edition (January 12, 2008.*
c) *Materials Science and Engineering: An Introduction - Callister (John Wiley and Sons; ISBN 0-471-13576-3), 6th edition, 2002.*
d) *Science and Engineering of Materials - Askland and Phule (Thomson; ISBN 0-534-55396-6), 5th edition, 2005.*
e) *An Introduction to Tissue-Biomaterial Interactions- Kay C. Dee et al. (Wiley-Liss, 1st edition, 2002).*

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Understand the fundamental principals in biomedical engineering, material science and chemistry, and how they contribute to biomaterial development and performance.
CO-2	Able to apply the math, science, and engineering knowledge gained in the course to biomaterial selection and design.
CO-3	Able to classify materials into three main classes and describe their structure-property relationships for use in medical applications.
CO-4	Acquire knowledge of what to consider when selecting a material for an implant and their implications.
CO-5	Learn the mechanisms by which the human body reacts to a foreign material

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	3	3	3	-	1		3	3
CO-2	3	1	1	-	3	-	3	1
CO-3	3	-	-	-	2	1	3	3
CO-4	-	2	1	-	1	3	1	-
CO-5	3	2	3	-	1	1	3	-
Total	12	8	8	0	8	5	13	7
Average	3	2	2	0	2	2	3	2

Elective courses#13

1. Name of the Subject: ADVANCED MOLECULAR BIOLOGY

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Advanced Molecular Biology		3	1	0	4	4	20	50	30

3. Course Objectives:

I. To understand the basics of molecular biology and gene expression.
II. To understand DNA damage and repair systems
III. To impart an overview on the regulation of gene expression

4. Course Content:

Module I: Biochemical unity underlying biological diversity; DNA- interplay between form and function, flow of gene, molecular biology of DNA, RNA; Biosynthesis of purines and pyramidine nucleotides from ribose including regulation, salvage pathways Structure, types and function of nucleic acids (DNA & RNA) DNA Replication: Prokaryotic and eukaryotic DNA replication mechanism, enzymes and accessory proteins involved in DNA replication, gene expression (transcription and translation); Concept from chemistry to explain the properties of biological molecules.

Module II: Protein Synthesis: Prokaryotic transcription, eukaryotic transcription, RNA polymerases, General and specific transcription factors, Regulatory elements and mechanisms of transcription regulation, 5′ Cap formation, Transcription termination, 3′end processing and polyadenylation, nuclear export of mRNA, mRNA stability RNA splicing: Nuclear splicing, spliceosome and small nuclear RNAs, group I and group II introns, Cis- and Trans- splicing reactions, tRNA splicing, alternate splicing. Genetic Code, Prokaryotic and eukaryotic translation - Synthesis of aminoacyl tRNA, aminoacyl synthetases, Mechanism of initiation, elongation and termination, Regulation of translation, co-and post-translational modifications of proteins.

Module III: Regulation of gene expression: Induction and repression, operon theory, lac operon, trp operon, ara operon, attenuation, positive and negative control, catabolite repression, regulation of transcription by cAMP and CRP, and guanosine tetraphosphate, Run off transcription. Britten-Davidson and Mated models of gene regulation, regulation of gene expression in eukaryotes.

Module IV: Enzymes- Basic concepts, catalytic strategies; Carbohydrates; Lipid membranes; Membrane channels and pumps; signal transduction pathways, G- proteins. Metabolism- Basic concepts and design; Glycolysis, TCA, oxidative phosphorylation, integration of metabolism; Basic chromatin structure; Basic cell cycle including basic cancer biology; genetic engineering.

5. Text/Reference:

a) *Bruce Alberts, Alexander Johnson, Julian Lewis, Martin Raff, Keith Roberts, and Peter Walter, Molecular Biology of the Cell, 6th edition, Garland Science publishing, 2007.*
b) *Lodish, H., Berk, A., Kaiser, C.A., Krieger, M., Scott, M.P., Bretscher, A., Ploegh, H. and Matsudaira, P. (2007) Molecular Cell Biology (6th edn). W. H. Freeman, New York.*
c) *Molecular Biology of the Gene - J. D. Watson, N. H. Hopkins, J. W, Robertis , A. Steitz & A.M. Weiner, Benjamin cummings Publ. California – 1988.*
d) *Genes VII. - Benjamin Lewin, Oxford Univ. Press, Oxford (2000)*
e) *Molecular Biology – Freifelder, D, Narosa Publishing house New York, Delhi, 1987.*
f) *Advance Molecular Biology Twyman, R.M., Bios Scientific publishers Oxford 1998.*
g) *Essentials of Molecular Biology. D. Freifelder, Panima publishing corporation*.

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Understand the fundamental principles and apply the molecular biology techniques
CO-2	Analyze the experimental data to select a suitable molecular biology technique for their research
CO-3	Able to apply contextual and conditional knowledge of gene function for various applications
CO-4	Exemplify different molecular techniques including polymerase chain reactions and their applications
CO-5	Implement, organize and design different vectors for gene cloning and expression

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	3	3	3	-	1		3	3
CO-2	3	1	1	-	3	-	3	1
CO-3	3	-	-	-	2	1	3	3
CO-4	-	2	1	-	1	3	1	-
CO-5	3	2	3	-	1	1	3	-
Total	12	8	8	0	8	5	13	7
Average	3	2	2	0	2	2	3	2

Elective courses#14

1. Name of the Subject: COMPUTATIONAL FLUID DYANIMICS IN BIOLOGY

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Computational Fluid Dynamics in Biology		3	1	0	4	4	20	50	30

3. Course Objectives:

i. To understand the fundamental concept of computational fluid dynamics (CFD).

ii. To learn about different types of algorithm, governing equations apply in CFD.

4. Course Content:

Module I: Introduction to Computational Fluid Mechanics and Heat Transfer – Modeling of Transport Phenomena, Transport Equations – Conservation equation; mass; momentum and energy equations in dimensional and non – dimensional forms – Lagrangian and Eulerian forms; convective forms of the equations and general description. Overview of Numerical Methods; parabolic elliptic and hyperbolic equations; boundary and initial conditions; Approximate Solutions of Differential Equations; Variation Principles.

Module II: Concept of discretization - Taylor series FDM and CV based FVM – one dimensional unsteady state, fluid, mass, heat diffusion equation – Numerical solution of PDE – Explicit method – Stability – Convergence – Consistency, Thomas (tri-diagonal Matrix) Algorithm – Implicit method, Finite difference methods (FDM); different means for formulating finite difference equation; treatment of boundary conditions; boundary layer treatment; variable property; interface and free surface treatment; accuracy of FDM; Application of the method in bioengineering.

Module III: Finite volume methods (FVM); different types of finite volume grids; central, upwind and hybrid formulations and comparison for convection-diffusion problem; Properties of discretisation schemes; The quadratic upstream interpolation for convective kinetics (QUICK) scheme. Application of the method in bioengineering. Vorticity, stream function, upwind scheme – Central Difference scheme – Hybrid scheme – Power law scheme, Evaluation of pressure from equation of continuity, Pressure correction – Velocity correction, Simple Algorithm – Residues in solution – Relaxation, Iterative scheme – Over and under relaxation – quick updation, Discussion on SIMPLER, SIMPLE – C, Solution of coupled equations – Thermal buoyancy

Module IV: Finite Element Methods (FEM): Finite element methods; Rayleigh-Ritz, Galerkin and Least square methods; applications in bioengineering. Turbulence modeling: Reynolds averaged Navier-Stokes equations, RANS modeling, DNS and LES; applications in bioengineering. Validation of code and results.

5. Text/References:

a) Numerical Heat Transfer and Fluid Flow: S V Patankar. Taylor & Francis (Paperback Ed)

b) Computational Fluid Mechanics and Heat Transfer. J C Tannehill, D A Anderson and R H Pletcher Taylor & Francis (1997)

c) Computational methods for Fluid Dynamics: J H Ferziger and M Peric. Springer – Verlag (1999)

d) An introduction to computational fluid dynamics. The finite volume method: H. K. VERSTEEG and W. MALALASEKERA, Longman Group LTD., 1st edition, 1995.

e) Anderson, "Application of CFD method".

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Understand the fundamental concept of Computational Fluid Dynamics in Biology.
CO-2	Learn about different types of algorithms, governing equations apply in CFD.
CO-3	To Develop concepts of FEM, FDM & FVM and various others numerical schemes applicable to solve partial differential equations with respect to fluid flow and heat transfer, mass transfer and kinetics.
CO-4	To underline the principles of specific algorithm such as SIMPLE, Vortices stream function etc for steady and unsteady fluid flow problem. Develop the numerical algorithm and generate CFD code.
CO-5	Apply CFD code and software modeling, simulation, design purpose to solve the real-world problem.

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	3	3	3	3	3	1	3	3
CO-2	3	3	3	3	3	1	3	3
CO-3	3	3	3	3	2	2	2	2
CO-4	3	3	3	3	3	2	3	2
CO-5	3	3	3	3	3	1	3	2
Total	15	15	15	15	14	7	14	12
Average	3	3	3	3	2.8	1.4	3	2.5

Elective courses#15

1. Name of the Subject: IPR AND BIOSAFETY

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
IPR and Biosafety		3	1	0	4	4	20	50	30

3. Course Objectives:

I. This course is a potential introductory training for those entering research that involves potentially infectious material. It is our hope that it will become a staple in research training much like bioethics and biosafety.

II. Students will understand different types IPR

4. Course Content:

Module I: Introduction to Intellectual Property and its types; IPs of relevance to Biotechnology; Important agreements and treaties in general and specific to the field of Bioengineering; handling important databases for IPs.

Module II: Patent: definition and type; National & PCT filing procedure: Time frame, Cost, Precautions while patenting – disclosure/non-disclosure; Patent licensing and agreement Patent infringement meaning, scope, litigation.

Module III: Safety in therapeutic and diagnostic devices like defibrillator, pacemaker, artificial ventilators, patient monitoring system etc; Safety in biomedical implants and prostheses; Precautions in measurements of different physiological parameters; Safety and protocols in proper storage and maintenance of medical records; computers in health care, responsibility, checklists; biomedical waste management.

Module IV: Primary Containment for Biohazards; Biosafety Levels; Biosafety Levels of Specific Microorganisms; Recommended Biosafety Levels for Infectious Agents and Infected Animals; Safety in genetic and tissue engineering research; GMOs & LMOs; protocol of drug administration dosage and radiation dosage. Social and ethical implications of biological weapons.

5. Text/References:

a) *Bertil Jacobson and Alan Murray, Medical Devices: Use and Safety, Publisher: Churchill Livingstone; 1 edition, ISBN-10: 0443102597, ISBN-13: 978-0443102592.*

b) *Shayne C. Gad and Marian G. McCord, Safety Evaluation in the Development of Medical Devices and Combination Products, Publisher: CRC; 3 edition, ISBN-10: 1420071645, ISBN-13: 978-1420071641*

c) *Jose Justiniano and Venky Gopalaswamy, Practical Design Control Implementation for Medical Devices, Publisher: Informa Healthcare; 1 edition, ISBN-10: 1574911279, ISBN-13: 978-1574911275.*

d) *Shayne C. Gad, Safety Evaluation of Medical Devices, Publisher: CRC; 2 edition, ISBN-10: 082470617X, ISBN-13: 978-0824706173.*

e) *BAREACT, Indian Patent Act 1970 Acts & Rules, Universal Law Publishing Co. Pvt. Ltd., 2007*

f) *Kankanala C., Genetic Patent Law & Strategy, 1st Edition, Manupatra Information Solution Pvt. Ltd., 2007*

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Understand the basic issues of biosafety, bioethics and IPR
CO-2	Follow good laboratory procedures and practices
CO-3	Justify the design of confinement facilities at different Biosafety levels
CO-4	Understand the social and ethical issues related to plant, animal and modern biotechnology.
CO-5	Review international agreements and protocols for Biosafety.

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	1	1	3	2	3	3	3	3
CO-2	1	1	2	2	2	2	3	3
CO-3	1	1	3	2	2	3	3	3
CO-4	1	1	2	2	1	3	2	2
CO-5	-	1	2	2	2	1	3	1
Total	4	5	12	10	10	12	14	12
Average	**0.8**	1	2.4	2	2	2.4	2.8	2.4

Elective courses#16

1. Name of the Subject: ADVANCED BIOMEMS

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Advanced BioMEMS		3	1	0	4	4	20	50	30

3. Course Objectives:

I. The course focused on the basic principles and applications of BioMEMS and LOC technology to the areas of biomedicine, biology, and biotechnology

II. Will help the students to understand the concept of micro scale,microdevices and different micro techniques.

4. Course Content:

Module I: Typical MEMs and Microsystems, materials for MEMS: active substrate materials; manufacturing techniques in MEMS.

Module II: Mechanics for MEMs design- static bending of thin plates, mechanical vibration, thermomechanics, fracture and thin film mechanics. Mechanical sensors and actuators, pressure and flow measurements, Thermal sensors and actuators, Shape memory alloys: Inertia sensor, flow sensor.

Module III: Parallel plate capacitor, pull in effect, Electrostatic sensors and actuators- Inertia sensor, Pressure sensor, flow sensor, tactile sensor, comb drive. Properties of piezoelectric materials, Piezoelectric sensor and actuator – inchworm motor, inertia sensor, flow sensor.

Module IV: Recapitulation of fluid dynamics principles, fluid flow in microconduits, in submicrometer and nanoscale. Microscale fluid, fluid actuation methods, dielectrophoresis, microfluid dispenser, microneedle, micropumps-continuous flow system, micromixers. Application of BioMEMS.

5. Text/References:

a) Steven S. Saliterman, Fundamentals of BioMEMS and Medical Microdevices; SPIE Publications (1st ed.); 2006.

b) Albert Folch, Introduction to BioMEMS; CRC Press (1st ed.); 2012.

c) Chang Liu, " Foundations of MEMS", Pearson Education International, New Jersey, USA, 2006

d) Ellis Meng, Biomedical Microsystems, CRC Press,Boca Raton, FL, 2011.

e) Tai Ran Hsu, MEMS and Microsystems design and manufacture, Tata McGraw Hill Publishing Company, New Delhi, 2002.

f) Wanjun Wang, Steven A.Soper — BioMEMS- Technologies and applications‖, CRC Press,BocaRaton,2007

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Have a concept on the scope and recent development of the science and technology of micro-and nano-systems
CO-2	Ability to design the micro devices, micro systems using the MEMS fabrication process.
CO-3	Gain a knowledge of basic approaches for various sensor design
CO-4	Gain a knowledge of basic approaches for various actuator design
CO-5	Will learn about the use of MEMS in biological field

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	1	1	3	3	3	3	3	2
CO-2	-	1	2	2	2	2	3	3
CO-3	1	1	3	1	3	3	3	1
CO-4	1	2	2	2	1	3	2	2
CO-5	1	2	2	2	3	1	3	1
Total	4	7	12	10	12	12	14	9
Average	**0.8**	1.4	2.4	2	2.4	2.4	2.8	1.4

Elective courses#17

1. Name of the Subject: ADVANCED BIOMECHANICS

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Advanced Biomechanics		3	1	0	4	4	20	50	30

3. Course Objectives:

I. The objective of this course is to provide you with an overview of the major challenges in movement biomechanics and experience with the engineering tools we use to address these challenges.

II. Will learn about different types of fluid,different types of joints FEA and its analysis

4. Course Content:

Module I: Principle of continuum mechanics; State of stress and strain in three-dimension (3D); traction vector; Cauchy's equation; Stress invariants; Green and Almansi strain; constitutive relations; elastic material models; constitutive relations; Viscoelasticity: definition and characteristics; different viscoelastic material models.

Module II: Properties of Newtonian and non-Newtonian fluids; Governing equations of fluid mechanics; field approach; control volume; Rheological properties of biological fluids; Hemodynamics; blood flow and arterial diseases.

Module III: Mechanical properties and types of human bone; elastic and dynamic model of bone; multi-body kinetic and dynamic analysis of limbs; Sports biomechanics. biomechanical response during impact. Injury risk assessment; Mechanics of soft tissues; constitutive models. Cardiovascular Mechanics; Mechanics of digestive systems; Stability of organs: zero-stress state.

Module IV: Introduction to Finite Element Analysis (FEA); Discretization of the domain; Different types of elements; Derivation of element matrices and vectors; Nodal solution; Assembly of nodal matrices; Application of FEA in biomechanics.

5. Text/References:

a) *Y C Fung, Biomechanics: Mechanical Properties of Living Tissues, springer, 2nd edition, 1993.*

b) *Nihat Ozkaya and margarita Nordin, Fundamentals of biomechanics-equilibrium, motion and deformation, springer-verlag, 2nd edition 1999.*

c) *D. Dowson & V. Wright, An introduction to Biomechanics of joints and joint replacements, Mechanical Engineering Publications, 1980.*

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Develop ability to analyze the kinetics and kinematic motions
CO-2	Analyze the mechanics of different types of biological fluids, soft tissues and connective tissue.
CO-3	Analyze the mechanics of different types of joints.
CO-4	Develop ability to analyze the muscle activity in various postures
CO-5	Identify and use engineering tools that are used to study movement and Apply biomechanics principles to "real-world" clinical and biomechanical research.

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	1	2	3	3	2	3	3	3
CO-2	1	2	2	3	2	2	2	3
CO-3	2	1	3	2	2	3	3	3
CO-4	1	2	2	3	2	3	2	2
CO-5	2	2	2	2	2	1	-	1
Total	7	9	12	13	10	12	10	12
Average	1.4	1.8	2.4	2.6	2	2.4	2	2.4

Elective courses#18

1. **Name of the Subject:** ADVANCED BIOMEDICAL INSTRUMENTATION
2. **Credit Structure:**

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Advanced Biomedical Instrumentation		3	1	0	4	4	20	50	30

3. **Course Objectives:**
   I. Will learn about different types of Physiological signals, electrodes and recorders and devices
   II. Can be able to design and simulate different types of biomedical circuit.
4. **Course Content:**

Module I: Evolution of medical instrument, Explanation of generalized and biomedical instrumentation; Components of a medical instrumentation system, Transducers; Electrodes: types and applications; biopotential systems:lead system and recording methods, waveforms, frequency spectrum.

Module II: Pace makers - different types, modes, circuitry and application. DC defibrillators: types, modes, circuitry;patient monitoring system, Heart lung machine; Oxygenators, Pumps, Hemodialyser; Wearable Artificial Kidney, Respiratory aids.

Module III: Different diagnostic and therapeutic instruments; thermography: principles and applications; cryogenic techniques; fiber optic cables, endoscopy, laparoscopy; lithotripsy; biotelemetry.

Module IV: Diathermy: principle, types and application; Stimulators, Interferential therapy, Electrical safety.

5. **Text/References:**
   a) *J. Bronzino, Biomedical Engineering & Instrumentation, PWS Engg. Boston.3rd Edn.*
   b) *J. Enderle, Bioinstrumentation, Morgan & Claypool Publisher 2006.*
   c) *R. S. Khandpur, Handbook of Bio-Medical Instrumentation, Tata McGraw Hill, 2003.*
   d) *Cromwell, Weibell& Pfeiffer, Biomedical Instrumentation & Measurement, Prentice Hall, India, 2nd Edn. 2003.*
   e) *J. Webster, Bioinstrumentation, Wiley & Sons.2004.*
6. **Course Outcomes:**

No. of Course outcome	Name of the Course outcome
CO-1	Explain about measurements of parameters related to Biopotential recorders, electrodes, sensors and transducer.
CO-2	Analyze the working of pacemaker, defibrillator, PMS, heart lung machine and different medical equipment's.
CO-3	Analyze the working of different diagnostic instruments.
CO-4	Ability to understand different therapeutic instruments.
CO-5	Outline the importance of patient safety against electrical hazard

7. **CO-PO Matrices & CO-PSO Mapping of courses**:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	1	1	3	2	3	3	3	3
CO-2	1	1	2	2	2	2	2	3
CO-3	2	-	3	2	3	3	3	3
CO-4	-	1	3	2	1	3	2	2
CO-5	-	1	2	2	3	1	-	1
Total	4	4	13	10	12	12	10	12
Average	0.8	0.8	2.6	2	2.4	2.4	2	2.4

Elective courses#19

1. Name of the Subject: BIOSENSORS, TRANSDUCERS AND MEASUREMENT DEVICES

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Biosensors, Transducers and Measurement Devices		3	1	0	4	4	20	50	30

3. Course Objectives:

I. Will learn about different types of sensing elements and recording system.
II. Will learn about different types of transducers.

4. Course Content:

Module I: Sensing elements: Temperature sensing elements, Pressure sensing elements, Elastic elements, Flow sensing elements; fiber optic sensors, Photo acoustic sensors, PPG sensors; smart sensors.

Module II: Transducers: classification, performance, characteristics; Errors in the measurements using transducers.

Module III: Recording system: types and principles; clinical laboratory instruments: types and application.

Module IV: Blood-gas analyser: application and principle; pulmonary function analyzers: types and principles.

5. Text/References:

a) *J. Bronzino, Biomedical Engineering & Instrumentation, PWS Engg. Boston.3rd Edn.*
b) *J. Enderle, Bioinstrumentation, Morgan & Claypool Publisher 2006.*
c) *R. S. Khandpur, Handbook of Bio-Medical Instrumentation, Tata McGraw Hill, 2003.*
d) *Cromwell, Weibell& Pfeiffer, Biomedical Instrumentation & Measurement, Prentice Hall, India, 2nd Edn. 2003.*
e) *J. Webster, Bioinstrumentation, Wiley & Sons.2004.*
f) *Chandran Karunakaran, Kalpana Bhargava, Robson Benjamin; Biosensors and Bioelectronics; (1st Ed.); Elsevier; 2015*

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Describe the purpose and methods of measurements and know the different display and recording devices.
CO-2	Explain different display and recording devices for various applications.
CO-3	Know the principle of transduction, classifications and the characteristics of different transducers and study its biomedical applications
CO-4	Remember and understand the concepts, types, working and practical applications of important biosensors.
CO-5	Know some of the commonly used biomedical transducers

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	1	1	3	2	3	3	3	3
CO-2	1	1	2	2	2	2	2	3
CO-3	2	1	3	2	3	3	3	3
CO-4	1	1	1	2	1	3	2	2
CO-5	2	1	2	2	3	1	2	1
Total	7	5	11	10	12	10	12	12
Average	1.2	1	2.2	2	2.4	2	2.4	2.4

Elective courses#20

1. Name of the Subject: PROSTHETICS AND ORTHOTICS

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Prosthetics and Orthotics		3	1	0	4	4	20	50	30

3. Course Objectives:

i. Will able to explain the important properties of various types of materials: metals, ceramics, polymers, and composites and the relationships that exist between the structural elements of these materials and their characteristics.

ii. Will learn about the mechanical and failure behavior of these materials, along with techniques used to improve the mechanical and failure properties in terms of alteration of structural elements.

4. Course Content:

Module I: Definition, Concept of Rehabilitation: Types of Physical Impairments, Principles of Assistive Technology Assessment, Principles of Rehabilitation Engineering; Concepts in Sensory & Motor rehabilitation. Importance of medical Devices; Manufacturing techniques for medical devices.

Module II: Types of orthoses and prostheses, Advance and automated prosthetics and orthosis, externally powered and controlled orthotics & prosthetics, FES system, Restoration of Hand function, Restoration of standing and walking. Mobility Aids; Electronic Travel Appliances (ETA).

Module III: Types of deafness, hearing aids, application of DSP in hearing aids, Cochlear implants, Voice synthesizer, speech trainer.

Module IV: Classification of Visual Impairments, Prevention and cure of visual impairments, Visual Augmentation, Tactile vision substitution, auditory substitution and augmentation, tactile auditory substitution, Assistive devices for the visual impaired

5. Text/References:

a) J Joseph D. Bronzino, The Biomedical Engineering Handbook, Third Edition: Three Volume Set, CRC Press,2006.

b) MacLachlan M. and Gallagher P. Enabling Technologies – Body Image and Body Function, Churchill Livingstone, 2004.

c) Mann W.C. (ed). Smart Technology for Aging, Disability, and Independence – The State of The Science, Wiley, New Jersey, 2005.

d) Muzumdar A. Powered Upper Limb Prostheses – Control, Implementation and Clinical Application. Springer, 2004.

e) Rory A Cooper, An Introduction to Rehabilitation Engineering, Taylor & Francis, CRC press,2006.

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Will able to understand basic concept of rehabilitation
CO-2	Will able to understand different types of orthoses and prostheses
CO-3	Analyze different types of disability
CO-4	Learn about different types of aids for different disability
CO-5	Cam design the aids to help overcome the different disability

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	1	1	1	1	3	3	3	1
CO-2	1	-	1	1	2	3	1	-
CO-3	2	1	3	3	2	3	2	1
CO-4	1	1	3	3	2	3	1	3
CO-5	-	2	2	2	3	1	1	2
Total	5	5	10	10	12	13	8	7
Average	1	1	2	2	2.4	1.4	1.6	1.4

Elective courses#21

1. Name of the Subject: METABOLIC PROCESS AND ENGINEERING

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Metabolic Process and Engineering		3	1	0	4	4	20	50	30

3. Course Objectives:

i. Deep understanding on key metabolic processes that keeps the cells functional.
ii. Comprehensive overview on advancements and applications in metabolic engineering, and bottlenecks involved

4. Course Content:

Module I: Introduction to metabolic engineering, Cellular metabolism: solute transport process, catabolism and metabolic fueling reactions, biosynthesis of cellular building blocks, polymerization of building blocks, assembly processes, rare metabolic conversions and regulation

Module II: Comprehensive models of cellular reactions with stoichiometry and reaction rates for growth, nutrients, black box models, structured metabolic models, bioenergetics.

Module III: Monitoring and measuring the metabolome, Methods for the experimental determination of metabolic fluxes by isotope labeling metabolic fluxes using various separation-analytical techniques. GC-MS for metabolic flux analysis, genome wide technologies: DNA /phenotypic microarrays and proteomics.

Module IV: Network reconstruction, Genome scale metabolic models, Metabolic flux analysis of exactly/over/under determined systems, sensitivity analysis, Metabolic control analysis, Structure and flux analysis of metabolic networks, Validation; target prediction

Module V: Tools and applications, case studies: Metabolic engineering examples for bio-fuel, bio-plastic and green chemical synthesis

5. Text/References:

a) *Christinia D Smolke. The Metabolic Pathway Engineering Handbook. Fundamentals. CRC Press, Finland 2010.*
b) *Christinia D Smolke. The Metabolic Pathway Engineering Handbook. Tools and applications. CRC Press, Finland 2010.*
c) *Greogory N Stephanopoulos. Metabolic Engineering: Principles and Methodologies. Academic Press, UK, 1998*.

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	To understand the basics of various reaction, process and their interlinkages in a biological system
CO-2	To understand and design the various mathematical cellular models
CO-3	To understand the various methodologies utilized for improving cellular models.
CO-4	To build up a genome scale metabolic model and further analysis with implementation
CO-5	To understand the different modern tools developed for metabolic engineering and case studies

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	2	2	2	2	2	2	3	-
CO-2	2	2	2	3	2	2	3	-
CO-3	2	2	2	3	2	2	3	3
CO-4	2	2	2	3	2	2	3	3
CO-5	2	2	2	3	2	2	3	3
Total	10	10	10	14	10	10	15	9
Average	2	2	2	2.8	2	2	3	3

Elective courses#22

1. Name of the Subject: SYSTEMS BIOLOGY

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Systems Biology		3	1	0	4	4	20	50	30

3. Course Objectives:

I. *A deep understanding on the sources, recent methods, applications, different approaches involved in Systems Biology.*
II. *Students will both acquire and apply the new knowledge in understanding the different case studies*

4. Course Content:

Module I: Introduction to Systems Biology and fundamentals; Laboratory techniques used in systems biology studies; Panomic technologies; Systems biology markup language

Module II: Kinetic modeling: enzyme kinetics, allosteric enzymes, transporters, models of biochemical pathways; case studies and demonstration;

Module III: Gene expression networks, Genetic circuits, oscillators, switches, Lambda phage multistability, Chemotaxis, mechanistic models for different biochemical processes involved in the eukaryotic cells

Module IV: Developmental Systems Biology: Introduction, Quorum sensing, Drosophila development

5. Text/References:

a) *Uri Alon, An Introduction to Systems Biology: Design Principles of Biological Circuits, Chapman & Hall/CRC Press,Â Mathematical and Computational Biology, 2nd edition, 2007.*
b) *Zoltan Szallasi, JörgStelling, and Vipul Periwal, System Modeling in Cellular Biology: From Concepts to nuts & bolts. The MIT Press, Massachusetts.*
c) *Demin O, Goryanin I., Kinetic Modelling in Systems biology. CRC Press. 2009. ISBN 978-1-58488-667-9*

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	To understand pan omic technologies and their significance in Systems Biology
CO-2	To design mathematical models for biological reactions dealt with enzymes, and proteins
CO-3	To design mathematical models and simulation for gene expression and different biochemical processes
CO-4	To employ different modelling and simulation tools, and SBML
CO-5	To employ systems biology studies in simple organisms.

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	2	2	2	3	3	3	3	3
CO-2	3	2	2	3	-	3	3	-
CO-3	3	2	2	3	-	3	3	-
CO-4	2	2	2	3	-	3	3	-
CO-5	2	3	2	3	3	3	3	3
Total	12	11	10	15	6	15	15	6
Average	2.4	2.2	2	3	1.2	3	3	3

Elective courses#23

1. Name of the Subject: BIOSTATICS

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Biostatics		3	1	0	4	4	20	50	30

3. Course Objectives:

i. Introduce the students to basic statistical operations required in the field of biotechnology and biochemical engineering.
ii. Application of gained knowledge in different statistical problems related to biotechnology.

4. Course Content:

Module I: Fundamentals of statistics in biology; Probability: Permutations; Combinations; Inclusion-exclusion rule; Sampling with and without replacement; Conditional probability: Bayes' theorem; Independence; Descriptive statistics and Random variables; Measures of central tendency; Measures of spread; Higher moments: kurtosis, skewness, Statistical data representation; Discrete random variables: Bernoulli, Binomial, Poisson; Geometric distributions; Continuous random variables: Normal; Exponential distributions; Standard normal distribution.

Module II: Samples and populations; Single- and Double-blind experiments; Point and interval estimates; Sampling distributions: t, chi-square, F distributions; Hypothesis testing: null and alternative hypotheses, decision criteria, critical values, type I and type II errors, Meaning of statistical significance; Power of a test; One sample hypothesis testing: Normally distributed data: z, t and chi-square tests; Binomial proportion testing. Two sample hypothesis testing; Nonparametric methods: signed rank test, rank sum test; Kruskal-Wallis test; Analysis of variance: One-way ANOVA.

Module III: Regression and correlation; Analysis of enzyme kinetic data; Michaelis-Menten; Lineweaver-Burk and the direct linear plot; Logistic Regression; Polynomial curve fitting.

Module IV: Single factor experiments; Randomized block design; Plackett-Burman Design; Comparison of k treatment means; Factorial designs; Blocking and confounding; Response surface methodology.

5. Text/References:

a) Hogg R.V. and Tanis E.A.(2001). Probability and Statistical Inference, Prentice Hall International Inc.
b) Kale, B.K. (1999). A first Course on Parametric Inference, Narosa Publishing House.
c) Manly, B. F. (2007). Randomization, Bootstrap and Monte Carlo methods in Biology, Chapman & Hall / CRC.
d) Rohatgi, V.K. and Saleh, A.K.Md.(2001). An Introduction to Probability and Statistics, John Wiley & Sons.

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Recognize the importance of data collection and its role in determining scope of inference.
CO-2	Demonstrate a solid understanding of interval estimation and hypothesis testing.
CO-3	Choose and apply appropriate statistical methods for analyzing one or multiple variables.
CO-4	Use technology to perform descriptive and inferential data analysis to interpret statistical results correctly, effectively, and in context.

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	3	1	2	2	2	1	2	1
CO-2	3	1	2	2	2	1	2	1
CO-3	3	1	2	2	2	1	2	1
CO-4	3	1	2	2	2	1	2	1
Total	12	4	8	8	8	4	8	4
Average	3	1	2	2	2	1	2	1

Elective courses#24

1. Name of the Subject: ADVANCED GENETIC ENGINEERING

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Advanced Genetic Engineering		3	1	0	4	4	20	50	30

3. Course Objectives:

I. To provide the basic and advanced concept of genetic engineering and their application in the field of Biotechnological and biomedical research.
II. To familiarize the students with different cutting-edge techniques employed in genetic engineering.
III. To provide the precise knowledge of ethical issues involved in the gene manipulation.

4. Course Content:

Module-I: Introduction to DNA modification enzymes**,** PCR and its Applications in molecular diagnostics, Chromatin Immunoprecipitation; DNA-Protein Interactions-Electromobility shift assay; DNaseI footprinting; Methyl interference assay

Module-I: Cloning Vectors: Plasmids; Insertion and Replacement vectors; Yeast vectors, Cosmids; Artificial chromosome vectors (YACs; BACs); Animal Virus derived vectors, Plant virus derived vectors, Plant based vectors, Expression vectors and their application; Intein-based vectors.

Module-III: Introduction to Cloning Methodologies: Insertion of foreign DNA into bacterial, yeast, plant and animal host Cells; Transformation and Transfection process; Construction of libraries; Isolation of mRNA and total RNA; cDNA and genomic libraries; cDNA and genomic cloning; Expression cloning; Jumping and hopping libraries; Southwestern and Far-western cloning; Protein-protein interactive cloning and Yeast two hybrid system; Phage display;

Module IV: DNA Sequencing methods; Concept of site directed mutagenesis, PCR based mutagenesis, Mutation detection: SSCP, DGGE, RFLP, Oligo Ligation Assay (OLA), MCC (Mismatch Chemical Cleavage, ASA (Allele-Specific Amplification), PTT (Protein Truncation Test). Principle and application of gene silencing; Gene knockouts and Gene Therapy; Gene targeting; Transgenics; cDNA and intragenic arrays; Differential gene expression and protein array, CRISPR-Cas9 system for gene editing.

5. Text/References:

a) *S.B. Primrose, R.M. Twyman and R.W.Old; Principles of Gene Manipulation. 6th Edition, S.B.University Press, 2001.*
b) *J. Sambrook and D.W. Russel; Molecular Cloning: A Laboratory Manual, Vols 1-3, CSHL, 2001.*
c) *Brown TA, Genomes, 3rd ed. Garland Science 2006*
d) *Selected papers from scientific journals.*
e) *Technical Literature from Stratagene, Promega, Novagen, New England Biolab etc.*

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Acquire the basic knowledge of genetic engineering including the techniques of gene manipulation, applications and limitations
CO-2	Understand the principles of gene expression and regulation in prokaryotic and eukaryotic cells
CO-3	Gain the knowledge of cutting-edge technologies like genome sequencing, silencing and editing
CO-4	Apply genetic engineering principles for advanced gene therapy, biotechnological and biomedical applications

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	-	-	3	2	1	2	3	3
CO-2	1	1	2	3	-	2	2	2
CO-3	2	2	2	2	3	2	3	2
CO-4	3	2	3	3	3	2	2	3
Total	6	5	10	10	7	8	10	10
Average	2	1.6	2.5	2.5	2.3	2	2.5	2.5

Elective courses#25

1. Name of the Subject: MOLECULAR THERAPEUTICS

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Molecular Therapeutics		3	1	0	4	4	20	50	30

3. Course Objectives:

I. To provide the students an ability to understand the application of biotechnological research in the field of molecular drug development.

II. To provide in-depth knowledge of recent developments in molecular therapeutics specifically in the treatment of critical illness.

III. To understand the recent advances of recombinant technology for the development of growth factors, hormones, vaccines and monoclonal antibodies.

4. Course Content:

Module-I: *Gene therapy:* Intracellular Barriers to gene delivery; Overview of inherited and acquired disease for gene therapy; retro and adenovirus mediated gene transfer; Liposome and nanoparticles mediated gene delivery; ***Gene silencing technology:*** antisense therapy: siRNA cellular therapy; Stem cells: definition properties and potency of stem cells; Sources: embryonic and adult stem cells; Concept of tissue engineering; Role of scaffolds; Role of growth factors; Role of adult and embryonic stem cells; Clinical applications; Ethical issues.

Module-II: *Recombinant Therapy*: Clinical applications of recombinant technology; Erythropoietin; insulin analogs and its role in diabetes; Recombinant human growth hormone; Streptokinase and urokinase in thrombosis; Recombinant coagulation factors; ***Immunotherapy*:** Monoclonal antibodies and their role in cancer; Role of recombinant interferon's; Immunostimulants: Immuno-suppressors in organ transplants; Role of cytokine therapy in cancers; ***Vaccines*:** types, recombinant vaccines and clinical applications; Tissue and organ transplantations: Transgenic and their uses; Cloning and ethical issues.

Module-III: Example of Medicinal plants, different metabolites including microbial source and plants, mode of action against different human disease.

5. Text/References:

a) *S.B. Primrose, R.M. Twyman and R.W.Old; Principles of Gene Manipulation. 6th Edition, S.B.University Press, 2001.*

b) *J. Sambrook and D.W. Russel; Molecular Cloning: A Laboratory Manual, Vols 1-3, CSHL, 2001.*

c) *Brown TA, Genomes, 3rd ed. Garland Science 2006*

d) *Selected papers from scientific journals.*

e) *Technical Literature from Stratagene, Promega, Novagen, New England Biolab etc.*

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Understand the underlying mechanism of wide range of disease therapies from protein supplementation to gene therapy.
CO-2	Acquire the Knowledge on Biopharmaceutical products and new molecular medications (antisense therapy).
CO-3	provide an ethical framework for the pursuit of clinical and laboratory research for stem cell therapy.
CO-4	Understand molecular basis of therapeutics and common drug modalities useful for the treatment of genetic disorders and Cancer.

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	3	3	3	3	-	2	2	2
CO-2	2	3	3	2	-	2	3	2
CO-3	2	3	-	3	3	2	2	2
CO-4	3	3	3	2	3	2	3	2
Total	12	12	9	10	6	8	10	8
Average	3	3	3	2.5	2	2	2.5	2

Elective courses#26

1. Name of the Subject: BIOENTREPRENEURSHIP

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Bioentrepreneurship		3	1	0	4	4	20	50	30

3. Course Objectives:

I. The students acquire necessary knowledge and skills required for organizing and carrying out entrepreneurial activities.
II. The students will develop their ability towards analysing various aspects of entrepreneurship – especially of taking over the risk, and the specificities as well as the pattern of entrepreneurship development and, finally, to contribute to their entrepreneurial and managerial potentials.

4. Course Content:

Module-I: Introduction to Bioentrepreneurship, Principles of business management and concept of Bioentrepreneurship, SWOT analysis of Indian Biobusiness, Project formulation and selection based on size, technological assessment, technical report, feasibility and commercial viability of project, total product cost, capital investment and profitability, manufacturing cost estimation, capital investment estimation, Risk capital and working capital, manufacturing cost estimation for an intracellular protein, using cost analysis for R&D decision making.

Module II: Introduction to IPR, types of IP (patent, copyrights, geographical indications, trademarks, trade secret, Industrial designs), treaties in IPR, Patent laws, Legislations covering IPR's in India, IPR Protection, patent filing in biotechnology, provisional and complete specification, patentable and non-patentable items.

Module III: General guidelines (GLP, GMP), containment facilities, types of containment, guidelines for recombinant DNA research, guidelines for cloning, Release of genetically modified organisms (GMOs), ISO Series, WHO Guidelines.

Module IV: Introduction and need of bioethics, types of risk associated with genetically modified microorganisms, Statutory requirements of social responsibility and entrepreneurial discipline, Example of a few Bioentrepreneurship.

5. Text/References:

a) *Biobusiness: A Strategic Perspective, Gurinder S. Shahi (Editor), 2005*
b) *Patent Law, P. Narayan*
c) *3. Biological Safety: Principles and Practices, Diane O. Fleming (Editor), Debra L. Hunt (Editor), 2006.*

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Comprehend business management and concept of Bioentrepreneurship
CO-2	Understand cost requirement for Bioentrepreneurship
CO-3	To understand the comprehend benefits of GM technology and related issues
CO-4	Identify the challenges faced on genetically modified organisms (GMOs)
CO-5	Recognize importance of protection of new knowledge and innovations and its role in business

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	2	3	2	-	2	2	3	2
CO-2	1	1	2	-	2	1	3	2
CO-3	2	-	2	1	2	1	3	2
CO-4	3	-	2	1	2	1	3	2
CO-5	1	1	1	2	2	2	3	2
Total	9	5	9	4	10	7	15	10
Average	1.8	1	1.8	0.8	2	1.4	3	2

Elective courses#27

1. Name of the Subject: PHARMACEUTICAL BIOTECHNOLOGY

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Pharmaceutical Biotechnology		4	0	0	4	4	20	50	30

3. Course Objectives:

i. The knowledge gained in this course would be used to understand and evaluate the different pharmaceutical parameters of the current and future biotechnology related products on the market

ii. The delivery of peptides and proteins by the parenteral, oral, transdermal and nasal routes of administration will also be discussed

4. Course Content:

Module I: Introduction, Industrial Applications- Biopharmaceuticals Role of r-DNA technology for the production of biopharmaceuticals - Engineering bacteria for industrial production of small valuable organics - Characterization and Bioanalytical Aspects of Recombinant Proteins as Pharmaceutical Drugs.

Module II: Monoclonal antibodies - applications of monoclonal antibodies - generation of monoclonal antibodies, Quality control and Stability of immunological products. Manufacturing process validation, Characterization of rDNA-derived biotherapeutics (Physiochemical characterization, biological activity)

Module III: Vaccines - Ideal Vaccine - types of modern vaccines - attenuated live vaccines - killed inactivated vaccines - conjugated vaccines - subunit vaccines - protein vaccines - DNA vaccines - lipid and carbohydrate antigen vaccines - recombinant live carriers - vaccine adjuvants - Scientific, Technical and Economic Aspects of Vaccine Research and Development, Basic approach to gene therapy

Module IV. Understanding of various dosage forms: solid/Liquid Dosages Forms, Semisolid Dosage Forms, Blood Products and Plasma Substitutes, Pharmaceutical Aerosols, Ophthalmic Preparations, Cosmeticology and Cosmetic Preparations.

5. Text/References:

a) Groves, J.M., Pharmaceutical Biotechnology, Taylor and Francis, London, 2nd edition, 2006.

b) Klefenz, H., Industrial Pharmaceutical Biotechnology, Wiley-Vch Verlag GmbH, Weinheim, 2nd edition, 2002. 2. Rodney, J.Y., Gibaldi, M, Biotechnology and Biopharmaceuticals, John Wiley, New Jersy, 2nd edition, 2003.

c) Pharmaceutical Biotechnology, Drug Discovery and Clinical Applications. Edited by O.Kayser andR.H.M¨uller (2006) Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim.

d) Walsh, G., Biopharmaceuticals: Biochemistry and Biotechnology, John Wiley, New Jersy, 2nd edition, 2003.

e) Rodney J Y Ho, MILO Gibaldi, Biotechnology & Biopharmaceuticals Transforming proteins and genes into drugs, 1st Edition, Wiley Liss, 2003.

f) Brahmankar D M, Jaiswal S B, Biopharmaceutics and Pharmacokinetics A Treatise, Vallabh Publisher, (1995, reprint 2008).

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Understand principles of biotechnology in pharmaceutical product development
CO-2	Role of r-DNA technology for the production of biopharmaceuticals
CO-3	Identify the challenges faced in development of biologicals and drugs
CO-4	Apply advanced biotechnology methods in novel drug delivery
CO-5	Review the production processes for various dosage forms

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	2	1	2	1	2	2	3	2
CO-2	2	1	2	1	2	2	3	2
CO-3	2	2	2	-	2	1	2	2
CO-4	3	-	2	1	2	1	2	2
CO-5	1	2	1	2	2	2	3	2
Total	10	6	9	5	10	8	13	10
Average	2	1.2	1.8	1	2	1.6	2.6	2

Elective courses#28

1. Name of the Subject: PROCESS CONTROL AND INSTRUMENTATION

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Process Control and Instrumentation		4	0	0	4	4	20	50	30

3. Course Objectives:

i. The students will have an appreciation of the fundamental importance of control systems for the safe and sustainable operation of process plants.
ii. The student will apply the key concepts of automatic control and instrumentation to process plants

4. Course Content:

Module I: Representative process control problems in biotechnology and biomedical engineering; general modeling principles in control theory; classification of variables and design elements of a control system.
Module II: Concept of ODE and Laplace Transform (LT) and its application in control systems; Transfer function for different types of processes; stability issues, unstable and non-minimum phase behaviour.
Module III: Electronic controllers, operational amplifier, electronic controller input and output, PID and on-off control models, microprocessors, general architecture, algorithms, applications in biological system control; Feedback controller.
Module IV: Design of feedback controller: performance evaluation, stability, sensitivity and robustness analysis; characteristics and performance of control computers, signals-types, signal transmission, analog feedback control systems. The direct digital control concept, advantages of DDC, computer process interface for data acquisition and control and analysis, computer control loops and software tools utilized.

5. Text/References:

a) George Stephanopolous; Chemical Process Control: An introduction to Theory and Practice; Prentice Hall of India; New Delhi, 1990.
b) Emanule S. Savas; Computer control of industrial processes, McGraw Hill, London, 1965.
c) Peter Harriot; Process Control, Tata McGraw Hill Publishing Co, New Delhi 1977.
d) Jon B. Olansen, Eric Rosow; Virtual Bio-Instrumentation: Biomedical, Clinical, and Healthcare Application in LabVIEW; Prentice-Hall; 2001.
e) George Buckbee, Joseph Alford; Automation Applications in Bio-pharmaceuticals; ISA; 2008.
f) Denis Dochain; Automatic Control of Bioprocesses; Willey; 2013.

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	To understand the basic principles & importance of process control in industrial process plants;
CO-2	To understand the use of block diagrams & the mathematical basis for the design of control systems;
CO-3	Design of various process controllers
CO-4	Appropriately select the instruments for a particular process
CO-5	Design and implement a safety instrumentation system

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	1	1	2	1	1	1	3	2
CO-2	1	1	1	2	2	1	2	3
CO-3	2	1	1	2	1	1	2	2
CO-4	3	1	1	1	1	2	2	3
CO-5	1	1	1	2	1	1	3	2
Total	10	6	9	5	10	8	12	12
Average	2	1.2	1.8	1	2	1.6	2.4	2.4

Elective courses#29

1. Name of the Subject: ENVIRONMENTAL BIOTECHNOLOGY

2. Credit Structure:

Course Name	Code	L	T	P	H	Credit	Marks (Weightage)		
							Mid	End	Internal
Environmental Biotechnology		4	0	0	4	4	20	50	30

3. Course Objectives:

I. To provide technical knowledge about biological waste treatment and pollution abatement in aquatic system
II. To provide students an ability to design effluent treatment plant.
III. To provide students an ability to understand application of biotechnology and biochemical engineering in the field of environmental remediation

4. Course Content:

Module I: Basics of environmental microbiology, stoichiometry and bacterial energetics, microbial kinetics and reactors

Module II: Introduction to aerobic suspended growth biological treatment, activated sludge treatment, characteristics of activated sludge, process configurations, aeration systems, bulking and other sludge settling problems, analysis and design of activated sludge, analysis and design of settlers

Module III:

Introduction to aerobic attached growth biological treatment systems, trickling filter, oxygen transfer and utilization.

Module IV:

Biological nutrient removal: microbiology, process description and environmental factors for nitrification, denitrification and phosphorous removal

Module V: Bioremediation: scope and characteristics of contaminants, biodegradability, contaminant availability for biodegradation, engineering strategies for bioremediation, biosorption.

5. Text/References:

a) *Brock Biology of Microorganisms By Michael T Madigan, John M. Martinko, Paul V. Dunlap, David P. Clark*
b) *Environmental Biotechnology: Principles and applications by Bruce E Rittmann and Perry L McCarty*

6. Course Outcomes:

No. of course outcome	Name of the course outcome
CO-1	Ability to understand the role of biotechnology in an environmental context
CO-2	Ability to apply engineering skills for solving environmental challenges
CO-3	Ability to understand the principle of bioremediation
CO-4	Ability to understand the principle of biological wastewater treatment

7. CO-PO Matrices & CO-PSO Mapping of courses:

CO & PO/PSO mapping	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PSO-1	PSO-2
CO-1	2	3	2	2	3	2	2	2
CO-2	3	2	2	2	2	2	2	1
CO-3	3	2	2	2	2	2	2	2
CO-4	2	3	3	2	3	3	2	2
Total	10	10	9	8	10	9	8	7
Average	2.5	2.5	2.25	2	2.5	2.25	2	1.75