B. Tech. (Biotechnology)

Syllabus 2023 onwards

Third SEMESTER

BIT2101 Cell and Microbiology [3-1-0-4]

Cell Biology: Cell structure - Prokaryotic and Eukaryotic Cell Structures, Bacterial cell division, Mitosis and Meiosis. Classification, structure and general characteristics of bacteria and viruses and fungi.

Microbial nutrition and, growth: Common nutrient requirements, nutritional types, culture media, pure culture, microbial growth – batch culture and continuous culture, growth curve, measurement of growth, influence of environmental factors on growth.

Sterilization and Disinfection: Physical and Chemical Methods.

Current trends in Microbiology: Biosafety, Remote sensing microbiology, Barcoding of microbes - application in clinical and industrial fields, Emergence of MDR and XDR microbes, Microbes in nanotechnology, Microbes as biological weapons.

References

1. Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K., and Walter, P., *Molecular Biology of the Cell* (7th ed.), WW Norton & Co, 2022.
2. Lodish, H., Berk, A., Kaiser, C. A., Krieger, M., Scott, M. P., Bretscher, A., Ploegh, H., and Matsudaira, P., *Molecular Cell Biology* (6th ed.), W. H. Freeman & Co., 2007.
3. Krebs, J.E., Goldstein, E.S., Kilpatrick, S.T., *Lewin's Genes XII* (12th ed.), Jones & Bartlett Learning, 2017.
4. Glick, B. R., and Pasternak, J.J., *Molecular Biotechnology: Principles and applications of recombinant DNA* (6th ed.), American Society for Microbiology, 2022.
5. Craig, N.L., Green, R., Greider, C., Storz, G., and Wolberger, C., *Molecular Biology: Principles of Genome Function* (3rd ed.), OUP Oxford, 2021
6. Nelson, D. L. and Cox, M. M., *Lehninger Principles of Biochemistry* (8th ed.), W. H. Freeman & Co Ltd, 2021.
7. Pelczar, M.J., Chan, E.C.S., and Krieg, N. R., *Microbiology* (5th ed.), Tata Mc Graw Hill Education Pvt Ltd., 2006
8. Willey, J., Sandman, K., Wood, D., *Prescott's Microbiology* (11th ed.), McGraw Hill, New York, 2019.

BIT2102 Biochemistry [3-0-3-4]

Introduction to Biochemistry: Definition and Scope of Biochemistry, Biomolecules and their role in living organisms, techniques for quantification of biomolecules.

Carbohydrate Biosynthesis pathways, their regulation, and metabolism: Gluconeogenesis, Glyoxylate, Glycolysis, Pentose phosphate pathway, Citric acid cycle, Oxidative Phosphorylation and Photophosphorylation, Photosynthesis, Respiration, and Electron transport chain.

Lipid Biosynthesis pathways, their regulation and metabolism: Fatty acids, Hormones, Neurotransmitters, Oxidation of Fatty acids, Transport of fatty acid, beta-oxidation, Ketone bodies

Protein Biosynthesis pathways, their regulation, and metabolism: Amino Acids, Structure of Protein, Protein folding, Amino acid oxidation and production of Urea - Metabolic fates of amino groups, Nitrogen excretion, and the urea cycle, Amino acid degradation, Nitrogen metabolism, Biosynthesis of amino acids

Nucleic acid Biosynthesis pathways, their regulation, and metabolism: Structure of DNA and RNA, Nucleotides Biosynthesis, and Nucleotides degradation.

Biomolecules associated with different disorders and their possible treatment.

Lab experiments related to quantification of biomolecules, enzymes, spectrophotometry, chromatography

References

1. Nelson, D. L. and Cox, M. M., *Lehninger Principles of Biochemistry* (8th ed.), W. H. Freeman & Co Ltd, 2021.
2. Berg, J.M., Gatto, G. J., Hines, J.K., Tymoczko, J. L., and Stryer, L., *Biochemistry* (10th ed.), W. H. Freeman & Co Ltd, 2023.
3. Conn, E., Stumpf, P. K., Bruening, G., and Doi, R. H., *Outlines of Biochemistry* (5th ed.), Wiley, 2009.
4. Voet, D. J., Voet, J. G., and Pratt, C. W., *Principles of Biochemistry* (4th ed.), Wiley, 2012

BIT2103 Transport Phenomena of Biological Processes [3-1-0-4]

Introduction to transport phenomena in biological systems, diffusion and convection, forces and fluid statics, Newtonian fluids and shear/strain relationships

Fluid transport: Principles of fluid mechanics, conservation equations, Fluidic applications: parallel-plate, rectangular and cylindrical channels, Differential forms of the conservation of mass and momentum: Navier Stokes, Integral forms of the conservation of mass and momentum, Blood rheology, Physiological and pathological blood flow and the cardiovascular system.

Heat transfer: Principles of heat transfer, heat transfer coefficients, heat transfer equipment – double pipe heat exchanger, shell and tube heat exchanger. Concept of evaporation and condensation.

Mass transport: Principles of mass transfer, Steady diffusion and boundary conditions, Steady state diffusion from variable geometries, Unsteady diffusion, Adsorption, Absorption, Extraction, Drying, Distillation, Transport in porous media.

Case studies pertaining to biological systems.

References

1. Bird R.B., Steward W.E., and Lightfoot E.N., *Transport Phenomena* (2nd ed.), Wiley, 2006
2. Geankoplis, C. J., *Transport Processes and Separation Processes Principles* (5th ed.), New Jersey, Pearson, 2018
3. Doran, P.M., *Bioprocess Engineering Principles* (2nd ed.), Elsevier, 2012.
4. Bailey, J. E., and D. F. Ollis, *Biochemical Engineering Fundamentals* (2nd ed.), McGraw-Hill Education, 2017.

5. Blanch, H. W. and Clark, D. S., *Biochemical Engineering* (2nd ed.), CRC Press, 1997.
6. Truskey, G., Yuan, F., and Katz, D., *Transport Phenomena in Biological Systems* (2nd ed.), Pearson, 2009

BIT2120 Bioprocess Calculations [3-1-0-4]

Basic introductory concepts: Dimensions and Units, mole, molecular weight, choosing a basis, density, specific gravity, concentration, temperature, pressure and hydrostatic head, flow rates.

Material Balances with and without reactions: General strategy to solve material balance calculations, reacting systems, species mole balances, Element mass balance, combustion systems, concept of limiting and excess reactants, percentage conversion, yield and selectivity, material balance for multiunit systems, recycle, bypass, and purge calculations. Industrial applications of material balances.

Equilibrium Calculations: PVT properties of ideal and real gases, compressibility charts, Phase diagrams and phase rule, multiphase equilibrium.

Energy balance with and without reactions: laws of thermodynamics, heat capacity of gas, liquid, solid and mixtures, sensible heat change in gas and liquid, enthalpy change in phase transformation, enthalpy change accompanied by biochemical reaction, standard heat of reaction, heat of mixing and dissolution of solids, Hess's law, humidity chart, energy balance involving biochemical reaction.

References

1. Himmelblau, D. M., Riggs, J.B., *Basic Principles and Calculations in Chemical Engineering* (8th ed.), Pearson, 2012.
2. Felder, R. M. and Rousseau, R.W., *Elementary Principles of Chemical Processes* (3rd ed.), John Wiley & Sons, 2004.
3. Doran, P.M., *Bioprocess Engineering Principles* (2nd ed.), Elsevier, 2012.
4. Hougen, O.A., Watson, K.M., Ragatz, R.A., *Chemical Process Principles Part-I: Material and Energy Balances* (2nd ed.), CBS Publishers New Delhi 2004.

Fourth SEMESTER

BIT2201 Genetics and Molecular Biology [3-1-0-4]

Principles of Genetics: Genome Organization in prokaryotes and eukaryotes, DNA content and C-value paradox. Molecular structure of DNA and RNA, Forms of DNA and RNA, Introduction to laws of genetics, Gene interaction, and linkage, extra-chromosomal inheritance, Sex determination, sex-linked, sex-limited, and sex-influenced inheritance.

DNA Replication: DNA replication- Semi conservative replication - Replication in prokaryotes and eukaryotes, Mutation and its types, DNA repair systems - methylation, mismatch repair, Photo reactivation repair, SOS repair, recombination repair.

Transcription: Transcription in prokaryotes and eukaryotes, Role of sigma factor in transcription, role of promoters and enhancers. Post-transcriptional modifications.

Translation: Translation of prokaryotes and eukaryotes, post-translational modifications Regulation of gene expression in prokaryotes and eukaryotes, Gene silencing: antisense technique, RNA interference, Ribozymes.

Case studies

References

9. Friefelder, D., *Molecular Biology*, (6th ed.), Narosa Publication House, 2004.
10. Strickberger, M.W., *Genetics*, (3rd ed.), Pearson Education India, 2015.
11. Snustad, D.P., Simmons, M.J., *Principles of Genetics*, (7th ed.), Wiley, 2015.
12. Hyde, D.R., *Genetics and Molecular Biology*, (1st ed.), McGraw Hill Education, 2010

BIT2202 Bioreaction engineering and Bioenergetics [3-0-3-4]

Basics of Reaction Engineering Law of mass action and rate equation, definitions and examples of elementary and nonelementary reactions, theories of reaction rate and temperature dependency, analysis of experimental reactor data - evaluation of rate equation by integral and differential analysis for constant volume system. Ideal and non-ideal reactors. RTD.

Metabolic stoichiometry and energetics: thermodynamic principles, metabolic reaction coupling ATP and NAD, carbon catabolism, respiration, photosynthesis, biosynthesis, transport across cell membrane, metabolic organization and regulation, end products metabolism, stoichiometry of cell growth and product formation.

References

1. Levenspiel, O., *Chemical Reaction Engineering*, (3rd ed.) Wiley, 2021.
2. Fogler, H., *Elements of Chemical Reaction Engineering*, (6th ed.), Pearson Education Limited, 2022.
3. Ozilgen, M., Sorguven, E., *Bio-Thermodynamics Principles and Applications*, (1st ed.), CRC Press, 2016.
4. Nelson, D.L., Cox, M.M., *Lehninger Principles of Biochemistry*, (8th ed.), W.H. Freeman and Co Ltd., 2021.
5. Smith, J.M., Van Ness, H.C., and Abott, M.M., *Introduction to Chemical Engineering Thermodynamics*, (7h ed.) McGraw Hill, 2012.

BIT2220 Bioprocess Engineering [3-1-0-4]

Media preparation and its sterilization: Media ingredients, its formulation and optimization, Media sterilization, design of batch sterilization processes. Sterilization of media by membrane filters. Design of continuous sterilization processes, Air sterilization.

Cell growth, substrate utilization and product formation kinetics: Inoculum preparation for bacterial and fungal cultures, Criteria for inoculum transfer, Aseptic methods of inoculation. Quantification of cell growth, growth patterns and kinetics in batch culture, environmental factors affecting growth kinetics, heat generation by microbial growth, kinetics of substrate utilization, Yield and maintenance coefficients, kinetics of product formation.

Operating considerations for bioreactors: Choosing the cultivation methods, Batch, fed batch and continuous mode of operation. Chemostat with cell recycle, Stability analysis.

References

1. Shuler M.L. and Kargi, K., *Bioprocess Engineering: Basic Concepts*, (2nd ed.), Pearson Education India. 2015.
2. J.E. Bailey, D.F. Ollis, Biochemical Engineering Fundamentals, (2e), McGraw Hill, 2017.
3. P. Doran, Bioprocess Engineering Principles, (2e), Elsevier, 2012.
4. H.W. Blanch, D.S. Clark Biochemical Engineering, (2e), CRC Press, New York, 1997.
5. Stanbury, P.F., Whitaker, A., Hall, S.J., *Principles of Fermentation Technology*, (3rd ed.), Butterworth-Heinemann Publ. House. 2016.
6. Mandenius, C.F., *Bioreactors: Design, Operation and Novel Applications*, Wiley, 2016.

BIT2221 Enzyme Technology [3-1-0-4]

Enzymes -Classification and types - Mechanisms of enzyme catalysis and action -Concepts of bioenergetics.

Kinetics of single substrate reactions and multi-substrate reactions, Mechanisms, and kinetics - Types of inhibition and Kinetic models - Allosteric regulation of enzymes

Extraction of enzymes from various sources like plant, animal, and microbial sources - Nature of extraction medium - Purification of enzyme - Criteria of purity - Determination of molecular weight of enzymes.

Enzyme immobilization - applications of enzymes in food, pharmaceutical, and other industries for analytical and diagnostic applications, Biosensors applications in industry, healthcare, and the environment

References

1. Shuler M.L. and Kargi, K., *Bioprocess Engineering: Basic Concepts*, (2nd ed.), Pearson Education India. 2015.
2. Palmer, T., *Enzymes: Biochemistry Biotechnology and Clinical Chemistry*, (2nd ed.), East West Press Pvt Ltd, New Delhi, 2008.
3. Chaplin, M. and Bucke, C. *Enzyme Technology*, (1st ed.), Cambridge University Press, London, 1990.
4. Lee, J., *Biochemical Engineering*, (1st ed.), Prentice-Hall Inc Publishers, Delhi, 1992.

BIT2240 Analytical Techniques in Biotechnology [3-0-0-3]

Electrophoresis: General principle, support media, Agarose, PAGE, Capillary electrophoresis, Continuous electrophoresis, Isoelectric focusing.

Chromatography: Theory of Chromatography and types (Paper, TLC, HPTLC, column, GC, HPLC) – their principles and applications.

Spectrophotometry: Working principle, instrumentation, sample preparation and its applications and types (UV-VIS, IR, Spectro-fluorometry), X-ray crystallography, Flame photometry, Circular Dichroism spectrophotometry

Centrifugation Techniques: working principle, instrumentation, different types of centrifuges (Analytical and preparative centrifugation), Ultracentrifugation methods.

Tracer techniques and Recent analytical tools: Radioactive and stable isotopes, pattern and rate of radioactive decay, Measurement of radioactivity, Principles of X-ray diagnosis, MRI, CT-scan, NMR.

References

1. Wilson, K., and Walker, J., *Principles and Techniques of Biochemistry and Molecular Biology*, (8th ed.), Cambridge University Press, UK, 2018.
2. Christian, G.D., Dasgupta, P.K. and Schug, K. A., *Analytical Chemistry* (Indian ed.), Wiley India Pvt. Ltd., India, 2020.
3. Fifield F.W., *Principles and Practice of Analytical Chemistry* (5th ed.), Blackwell, Scientific Publishers, 2016.

BIT2241 Food Biotechnology [3-0-0-3]

Food Science and Microbiology: Macro and micronutrients of food, role of nutrients, parameters of good food, microorganism in food, intrinsic and extrinsic parameters of food, rapid methods for identification of microorganism in food, food borne illness

Food Fermentation: Role of lactic acid bacteria in fermentation and strain improvement, Fermentation of meat, fish, vegetables, beverages, dairy product, non-beverage product, use of genetic engineering techniques for improved quality product.

Food processing, preservation and packaging: Sterilization techniques: Pasteurization, Irradiation, Dehydration, Low temperature, Canning, Mincing, Blanching, Milling, Methods and materials of food packaging, Drying, freezing, fermentation, Sugaring, Salting, Vacuum Packing, Use of additives and stabilizers.

Modified food: Fruit Ripening, Improvement in Sweetness and Flavor, Nutraceuticals, genetically modified food: Starch, Amino acid, Vitamin content, Single cell protein, Single cell oil, and Golden rice, Safety aspects of genetically modified food.

Food Safety and Control: Food contaminants and their source, techniques for detection of food contaminants, quality control and assurance, ISO series, regulatory bodies, Ethics, New trends in food technology

References

1. Many, N.S., and Shadaksharaswamy, M., *Foods Facts and Principles* (3rd ed.), New Age International (P) Limited, 2008.
2. Clark, S., Jung, S., and Lamsal, B., *Food Processing: Principles and Applications* (2nd ed.), Wiley and Blackwell, 2014.
3. Montville, T.J., Matthews, K.R., and Kniel, K. E., *Food Microbiology: An Introduction* (4th ed.), John Wiley & Sons, 2020.
4. Sharma, H.K., and Upadhyay A., *Food Engineering and Technology*, New India Publishing Agency, 2015.
5. Frazier, W.C., Westhoff, D.C., and Vanitha, N.M., *Food Microbiology* (5th ed.), McGraw Hill Education (India) Private Limited, 2014.
6. Nielsen, S.S., *Food Analysis* (5th ed.), *Food Science Text Series*, Springer, 2019.

BIT2242 Fundamentals of Heat and Mass Transfer [3-0-0-3]

Heat Transfer methods: Concept of conduction in solid, liquid and gas, Fourier law of heat conduction, Heat transfer by convection, Natural and Forced convection, Convection from vertical and horizontal planes, Thermal boundary, Individual and overall heat transfer co-efficient, Fouling factors. Heat transfer by radiation, black and gray body concepts.

Heat Transfer Equipment: Introduction to heat exchangers (Double pipe, Shell and tube type heat exchanger, Plate type heat exchangers), Boilers, Condensers and Evaporators, LMTD calculation, Effectiveness of heat exchanger.

Mass Transfer Methods: Molecular and turbulent diffusion, Fick's law, Molecular, Knudsen & surface diffusion Inter-phase mass transfer, Mass transfer coefficients, Mass transfer in fluidized bed reactor, Flow past solids and boundary layers.

Mass Transfer Operations: Different modes of drying operations, Batch and Continuous dryer, Crystallizer, Theory and classification of crystallization, Factor affecting nucleation and crystal growth rate, Extraction. Absorption and Adsorption

References

1. Treybal, R.E., *Mass Transfer Operations*, (3rd ed.), Mc Graw Hill Publication, 2017.
2. J.P. Holman, *Heat Transfer*, (10th ed.), Mc Graw Hill Publication, 2017.
3. John H. Lienhard IV, John H. Lienhard V, *A Heat Transfer: Textbook*, (5th ed.), Dover Publications Inc., 2020.
4. Dutta, B.K., *Heat Transfer Principals and Applications*, (2nd ed.), PHI Learning, 2023.
5. Nag, P.K., *Heat and Mass Transfer*, (3rd ed.), Mc Graw Hill Publication,2011.

BIT2270 Project Based Learning [0-0-2-1]

Project Based Learning will be practical / simulation-based study in the emerging areas.

BIT2231 Genetics and Molecular Biology Lab [0-0-2-1]

1. Preparation of reagents for isolating genetic materials
2. Total genomic DNA extraction
3. Quantification of DNA/RNA
4. Plasmid DNA isolation from bacteria
5. Transformation of pBR322 plasmid into E. coli by inducing a competent state
6. Isolation of RNA from animal cell lines
7. Gene mutation using UV treatment
8. Polymerase Chain Reaction (Semiquantitative PCR and Real-Time PCR)
9. Agarose Gel Electrophoresis
10. Sodium Dodecyl Sulphate-Polyacrylamide Gel Electrophoresis (SDS-PAGE)
11. Western Blotting
12. Restriction Digestion of Plasmid DNA using EcoRI and HindIII
13. Study of models on DNA and RNA structures
14. Probability and Statistics
15. Determination of linkage and cross-over analysis

BIT2230 Simulation Lab 2 [0-0-2-1]

1. Simulation of batch reactors for homogeneous reactions
2. Simulation of CSTR for homogeneous reactions
3. Simulation of PFR for homogeneous reactions
4. Process involving reaction and separation without recycle
5. Process involving reaction and separation with recycle
6. Case study – I - V

FIFTH SEMESTER

BIT3101 Bioinformatics [3-0-2-4]

Introduction: Biological Databases, structure and sequence analysis of biomolecules. **Sequence Analysis:** Introduction, types of Sequence alignment -Pairwise and Multiple sequence alignment, Global alignment, Local alignment, Dotplot, Different scoring methods, Substitution matrices (PAM and BLOSUM). Dynamic programming, NeedlemanWunsch algorithm, Smith-Waterman algorithm, Multiple Sequence Alignment methods (MSA), Scoring of a MSA, Progressive (CLUSTALW), Iterative and Hidden Markov Model (HMM), FASTA and BLAST algorithms. **Phylogenetic Analysis:** Phylogenetic tree and terminology, different methods of Phylogenetic tree prediction.

References

13. Baxevanis, A.D. and Francis, B.F., *Bioinformatics- A practical guide to analysis of Genes & Proteins*, John Wiley, 2002.
14. Attwood, T.K., Parry-Smith, D.J., *Introduction to Bioinformatics*, Pearson Education, 1st Edition, 11th Reprint 2005.
15. Mount, D.W., *Bioinformatics: Genome and Sequence Analysis*, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York. 2001
16. Zvelebil, M. and Baum, J. O., *Understanding Bioinformatics* (1st ed.), Garland Science, 2007.
17. Mount, D. W., *Bioinformatics: Sequence and Genome Analysis* (2nd ed.), Cold Spring Harbor Laboratory Pr, 2004.
18. Bourne, P. E., *Structural Bioinformatics* (2nd ed.), Wiley-Blackwell, 2011.
19. Durbin, R., Eddy, S. R., Krogh, A. and Mitchison, G., *Biological Sequence Analysis*, Cambridge University Press, 1998.

BIT3102 Bioseparation Processes [3-1-0-4]

Introduction to bio separations and purification: Products from industrial fermentation, biomass, protein, and valuable metabolites; various downstream process steps; bioproduct from cell culture-intracellular and extracellular. Cell disruption: mechanical, enzymatic, and chemical methods. Solid-liquid separation: filtration and centrifugation. Membrane separation: ultrafiltration, dialysis and reverse osmosis. Precipitation of proteins: salting out, and solvent induced precipitation. Chromatography: principles, techniques and methods of affinity chromatography, ion-exchange chromatography, hydrophobic interaction chromatography, and size exclusion chromatography. Polishing and improving stability of bioproducts: Crystallization, Leaching, and lyophilization, Case Studies.

References

5. Belter, P. A., Cussler, E. L. and Hu, W. S., *Bioseparations: Downstream Processing for Biotechnology*, Wiley–Blackwell, 1988.
6. Ladisch, M. R., *Bioseparations Engineering: Principles, Practice, and Economics* (1st ed.), Wiley, 2014.
7. Harrison, R. G., Todd, P., Rudge, S. R., and Petrides, D. P., *Bioseparations Science and Engineering* (2nd ed.), Oxford Academic, 2020.
8. Doran, P.M., *Bioprocess Engineering Principles* (2nd ed.), Elsevier, 2012.
9. Shuler, M.L., Kargi, F., *Bioprocess Engineering Basic Concepts*, (2e), Prentice Hall of India, 2017.

BIT3120 Bioprocess Plant Design [3-1-0-4]

General design information; Mass and energy balance; Flow sheeting; Piping and instrumentation; Materials of construction for bioprocess plants; Mechanical design of process equipment; Vessels for biotechnology applications; Design considerations for maintaining sterility of process streams and processing equipment; 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; Process economics; Bioprocess validation; Safety considerations; Case studies.

References

7. Flickinger, M.C., *Upstream Industrial Biotechnology Volume 2: Equipment, Process Design, Sensing, Control, and cGMP Operations* (2nd ed.), John Wiley & Sons, 2013
8. Vogel, H.C., Todaro, C.M., *Fermentation and Biochemical Engineering Handbook* (2nd ed.), New Jersey, Pearson, 2018
9. Henry C. Vogel, Celeste M. Todaro. *Fermentation and Biochemical Engineering Handbook: Principles, Process Design and Equipment* (2nd ed.), Elsevier, 2008.
10. Wittmann, C. and Liao, J.C., *Industrial Biotechnology: Products & processes*, Wiley_VCH. 2017.
11. McNeil, M., and Harvey, L.M., *Practical Fermentation Technology* (1st ed.), John Wiley& Sons, 2008.
12. Sinnott, R. and Towler, G., *Chemical Engineering Design*: *Principles, Practice & Economics Of Plant & Process Design*, cbspd, 2009.

BIT3122 Pharmaceutical Biotechnology [3-1-0-4]

Introduction: Drug and Pharmaceutical Industry, Good Manufacturing Practices (GMP) and Good Laboratory Practices (GLP). Regulatory aspects of quality control, pharmacopeia. **Pharmacokinetics:** Routes of drug administration, Absorption of Drugs - Passive and facilitated transport, Influence of pH on transport of molecules across membranes, Bioavailability. Distribution and Redistribution of drugs - Tissue storage, placental & brain transport. Biotransformation of drugs and types, Routes of excretion of drugs - Rate of Clearance and Plasma half-life. **Pharmacodynamics:** Principles and Mechanism of drug action on receptors, enzymes, ion channels and transporters. Transducer mechanism. DoseResponse Relationship, Therapeutic efficiency, Factors modifying drug action. **Pharmacovigilance -** Casualty assessment, Side, secondary and toxic effects of drugs, Accidental overdose of drugs and the treatment, Drug Intolerance and Drug allergy, Drug abuse and Treatment. Case studies on vaccine manufacturing.

References:

1. Laurence Brunton, Bjorn Knollmann, Randa Hilal-Dandan, Goodman and Gilman's - The Pharmacological Basis of Therapeutics, McGraw-Hill Education, 13th Edition 2018, ISBN: 978-1-25-958473-2.
2. Nicolay Ferrari, Rosanne Seguin, Oligonucleotide-Based Drugs and Therapeutics Preclinical and Clinical Considerations for Development, John Wiley & Sons, 1st Edition 2018.

BIT3140 Genetic Engineering [3-0-0-3]

Introduction to Genetic Engineering and DNA Structure: Overview of genetic engineering, History and development of genetic engineering, DNA structure and replication. Gene

Cloning and Vectors: Principles of gene cloning, types of vectors (plasmids, bacteriophages, cosmids), Cloning strategies and techniques, Modern vector systems: CRISPR-Cas9 delivery systems and viral vectors. cDNA Library and cDNA Synthesis: Construction of cDNA libraries. cDNA synthesis and cloning. DNA Analysis and Sequencing: PCR and DNA amplification, DNA sequencing methods (Sanger, Maxam-Gilbert), Next-generation sequencing (NGS): Illumina, Nanopore, and PacBio technologies.

Recombinant DNA Technology and Applications-Principles of recombinant DNA technology, Applications of genetic engineering (agriculture, medicine, biotechnology). Case Studies and Ethical Considerations- Case studies of genetic engineering applications, Ethical and social implications of genetic engineering. Current Trends and Future Directions- Current trends and future directions of genetic engineering.

References

1. Nicholl, D. S. T. (2008). An Introduction to Genetic Engineering (3rd ed.). Cambridge University Press.
2. Brown, T. A. (2016). Gene Cloning and DNA Analysis: An Introduction (7th ed.). Wiley-Blackwell.
3. Primrose, S. B. and Twyman, R. M., *Principles of Gene Manipulation*, Blackwell Science, 2006.

4. Lewin, B., *Genes IX, International Edition*, Pearson education, 2008

5. Korman, S. M. (2019). Gene Editing (2nd ed.). Springer.

6. Sambrook, J., & Russell, D. W. (2001). Molecular Cloning: A Laboratory Manual (3rd ed.). Cold Spring Harbor Laboratory Press.

BIT3141 Animal and Plant Biotechnology [3-0-0-3]

Culture media composition and growth conditions; Animal cell and tissue preservation; Anchorage and non-anchorage dependent cell culture; Kinetics of cell growth; Micro & macro-carrier culture; Hybridoma technology; Stem cell technology; Animal cloning; Transgenic animals; Knock-out and knock-in animals.

Totipotency; Regeneration of plants; Plant growth regulators and elicitors; Tissue culture and cell suspension culture system - methodology, kinetics of growth and nutrient optimization; Production of secondary metabolites; Hairy root culture; Plant products of industrial importance; Artificial seeds; Somaclonal variation; Protoplast, protoplast fusion - somatic hybrid and cybrid; Transgenic plants - direct and indirect methods of gene transfer techniques; Selection marker and reporter gene; Plastid transformation.

References

1. Glick, B. R., Pasternak, J. J., & Patten, C. L. (2022). *Molecular biotechnology: Principles and applications of recombinant DNA* (6th ed.). ASM Press.
2. Freshney, R. I. (2016). *Culture of animal cells: A manual of basic technique* (7th ed.). Wiley-Liss.
3. Slater, A., Scott, N. W., & Fowler, M. R. (2008). *Plant biotechnology: The genetic manipulation of plants* (3rd ed.). Oxford University Press.
4. Brown, T. A. (2020). *Gene cloning and DNA analysis: An introduction* (8th ed.). John Wiley & Sons.
5. Moo-Young, M. (Ed.). (2019). *Comprehensive biotechnology* (3rd ed.). Elsevier.

6. Sambrook, J., & Russell, D. W. (2001). *Molecular cloning: A laboratory manual* (3rd ed.). Cold Spring Harbor Laboratory Press.

BIT3142 Biomaterials [3-0-0-3]

Introduction and importance of biomaterials; Types of biomaterials: Metallic, ceramic, polymeric and composite biomaterials. Classification according to physiological response of biomaterials: bioinert, bioactive and bioresorbable biomaterials; Surface modifications; Surface analysis; Surface-protein interactions; Material-cell interactions: biocompatibility and rejection; Implants and infection; Applications of biomaterials in Tissue engineering, Drug delivery, Biosensing and Diagnostics (wearables), case studies.

References

1. Park, J.B. and Bronzino, J.D., *Biomaterials: Principles and Applications* (1st ed.), CRC Press, 2002.
2. Dee, K.C., Puleo, D.A., and Bizios, R., *An Introduction to Tissue-Biomaterial Interactions* (1st ed.), Wiley-Liss, 2002.
3. Hin T.S., *Engineering Materials for Biomedical Applications*, World Scientific Connect, 2004.
4. Rolando, B., *Integrated Biomaterials Science* (2nd ed.), Kluwer Academic/Plenum Publishers, 2002.

BIT3143 Environmental Biotechnology [3-0-0-3]

Introduction to Environmental Biotechnology; Major environmental Pollutants (Soil, water, and air); Renewable and sustainable sources and its classification; Biofuels; Biogas production using methanogenic bacteria; Microbial hydrogen gas production; Bioethanol production and its use as fuel, Cellulose degradation for combustible fuel; Photosynthetic pigments as solar energy convertors; Bionic Leaf.

Biofertilizers and biopesticides: Nitrogen fixing microorganisms, nitrogen fixation process, Phosphate solubilizers; Vermicompost; Plant growth promoting rhizobacteria. Microbiology of wastewater treatment (Biological processes for domestic and industrial wastewater treatments; Aerobic and anaerobic systems, reactors, Biofilms).

Bioremediation: different techniques of bioremediation; phytoremediation; Bioleaching; Wasteland reclamation, microbial degradation of Xenobiotics; pesticide and herbicide degradation; Case studies of municipal and household waste management.

References

1. Foster C.F., John Ware D.A., Environmental Biotechnology, Ellis Horwood Ltd.,1987.

2. Karrely D., Chakrabarty K., Omen G.S., Biotechnology and Biodegradation, Advances in Applied Biotechnology Series, Vol.4, Gulf Publications Co. London,1989.

3. Bioremediation engineering; design and application 1995 John. T. cookson, Jr. Mc Graw Hill, Inc.

BIT3170 Project Based Learning 3 [0-0-2-1]

Project Based Learning will be practical / simulation-based study in the emerging areas.

SIXTH SEMESTER

BIT3201 Immunology [3-1-0-4]

Introduction to Immunology, Types of Immunity, Cells of the Immune System and their roles and interactions, Mechanisms of lymphocyte movement and activation. Antigens, Antibodies, Genetic Mechanisms of Immunity, Regulation of antibody production. Monoclonal and Polyclonal Antibodies, Components of the complement system, Complement activation and regulation. Cytokines, Interleukins, and interferons production and their biological functions. Antigen-presenting cells; Major histocompatibility complex structure and function - Antigen processing and presentation, HLA typing. Immune Tolerance: Transplantation Immunology: Hypersensitivity: Case Study, Vaccines, immunodiagnostic Techniques, Antibody Engineering, Immunotherapy.

References

1. J. Owen, J. Punt, and S. Stranford, *Kuby Immunology*, 8th Ed., New York, NY: W.H. Freeman, 2018.
2. P. J. Delves and S. J. Martin, *Roitt's Essential Immunology*, 13th Ed., Hoboken, NJ: Wiley-Blackwell, 2017.
3. A. K. Abbas, A. H. Lichtman, and S. Pillai, *Basic Immunology: Functions and Disorders of the Immune System*,7th Ed., Philadelphia, PA: Elsevier, 2023.
4. K. M. Murphy, P. Travers, and M. Walport, *Janeway's Immunobiology*, Berlin: Springer Spektrum, 2014.
5. R. R. Rich, *Clinical Immunology*, 5th Ed., Philadelphia, PA: Elsevier, 2018.

BIT3244 Industrial Biotechnology [3-0-0-3]

Introduction to microorganisms and industrial products - Primary screening (screening for amylase, organic acid, antibiotic, amino acid and vitamin producing microorganisms) and secondary screening - Process flow sheeting- Basic concepts of upstream and downstream processing in bioprocess - Methods of strain improvement - inoculum media and inoculum preparation- Medium requirements for fermentation process - Types of fermentation processes - Scale up of fermentations - Process economics - production of primary and secondary metabolites - production and application of industrial enzymes - microbial biopesticides and biofertilizers, biopolymers, biofuels, recombinant products- Case studies.

References:

1. W. Cruger and A. Cruger, *A Textbook of Industrial Microbiology*, 2nd ed. New Delhi, India: CBS Publishers & Distributors, 2016.
2. A. H. Patel, *Industrial Microbiology*, 2nd ed. New Delhi, India: Laxmi Publications, 2016.
3. S. C. Prescott and C. G. Dunn, *Industrial Microbiology*, 4th ed. New Delhi, India: CBS Publishers, 2005.
4. P. F. Stanbury and A. Whitaker, *Principles of Fermentation Technology*, 3rd ed. Oxford, U.K.: Pergamon Press, 2016.

BIT3245 Protein Engineering [3-0-0-3]

Introduction to Protein Engineering: Protein folding, misfolding & aggregation, Protein expression & purification systems, post-translational modifications, Protein structure

determination (x-ray crystallography, NMR, Cryo-electron microscopy), Protein stability (enzymatic, thermodynamic and kinetic), Basic concepts for design of a new protein/enzyme molecule. Combinatorial protein engineering: Directed evolution, Site-directed mutagenesis, Rational engineering: Backbone reversal, Surface reengineering to prevent aggregation, Enzyme active site remodeling, De novo engineering: computational protein design methods, Case studies of protein engineering (e.g.: Dihydrofolate reductase, Subtilisin).

References:

1. S. J. Park and J. R. Cochran, *Protein Engineering and Design*, 1st ed. Boca Raton, FL, USA: CRC Press, 2009.
2. J. L. Cleland and C. S. Craik, *Protein Engineering: Principles and Practice*, 1st ed. New York, NY, USA: Wiley, 1996.

BIT3240 Nano-Biotechnology [3-0-0-3]

Introduction, history of nanotechnology, present and future of nanotechnology, properties of nanomaterials-Metal and semiconductor nanoparticles, Polymeric nanoparticles, Molecular nanoparticles, Forces at the nanoscale, The Nano-Bio interface. Nano biosensing-types of biosensors- optical and electrochemical biosensors, Applications of biosensors in molecule analysis; food safety, environmental and biomedical monitoring, and detection of biological weapons, Lab on chip devices for sensing and detection. Nanomedicine: Nanoparticles within a biological environment, Nanoparticle dynamics in biological media, nanoparticles for therapy, uptake and toxicology of nanomaterials, and Nanomaterials for tissue engineering and prosthetics. Nanoparticle-based bioimaging.

References

1. J. Ramsden, *Nanotechnology: An Introduction*, 1st Ed., Elsevier, 2011.
2. B. S. Murthy, *Textbook of Nanoscience and Nanotechnology*, Springer, 2013.
3. H. Summers, *Nanomedicine*, 1st Ed., Elsevier, 2013.
4. L. Stergios, *Nanomedicine and Nanobiotechnology*, Springer-Verlag, 2012.
5. C. M. Niemeyer and C. A. Mirkin, *Nanobiotechnology: Concepts, Applications and Perspectives,* Wiley-VCH, 2012.

BIT3241 Metabolic Engineering [3-0-0-3]

Basic concepts of Metabolic Engineering, Overview of cellular metabolism, Different models for cellular reactions, Metabolic regulation network at the enzyme level and the whole cell level, Examples of metabolic pathway manipulations, Metabolic pathway synthesis algorithms, Metabolic flux analysis and its applications, Methods for experimental determination of metabolic fluxes by isotope labelling, Analysis of metabolic control and the structure metabolic networks, Thermodynamics of cellular processes, New concepts for quantitative bioprocess research and development.

References

1. G. N. Stephanopoulos and A. A. Aristidou, *Metabolic Engineering: Principles and Methodologies*, 1st Ed., San Diego, CA: Academic Press, 1998.

2. C. D. Smolke, *The Metabolic Pathway Engineering Handbook: Fundamentals*, 1st Ed., New York, NY and London: CRC Press, 2010.
3. S. Cortassa, M. A. Aon, A. A. Iglesias, and D. Lloyd, *An Introduction to Metabolic and Cellular Engineering*, 2nd Ed., Singapore: World Scientific Publishing Co., 2011.
4. S. Y. Lee and E. T. Papoutsakis, *Metabolic Engineering*, 1st ed. New York, NY: CRC Press, 1999.
5. D. I. C. Wang, C. L. Cooney, A. L. Demain, P. Dunnill, A. E. Humphrey, and M. D. Lilly, *Fermentation and Enzyme Technology,* New York, NY: John Wiley & Sons, 1980.

BIT3242 Tissue Engineering [3-0-0-3]

Introduction - scope, therapeutic applications, cells as agents, growth dynamics-Measurement of cell & tissue characteristics: morphology, motility, ECM, mechanical & physical properties-Types/components of tissue, repair processes, and wound healing - growth factors (e.g., VEGF), cell-matrix/cell-cell interactions, telomeres, migration control - stem cell types, Sources, Potency, differentiation pathways, markers, FACS analysis, Organ-specific systems (liver, neuronal), Biomaterials- Properties, natural vs synthetic, biopolymers, Scaffolds and tissue engineering, Stem cell therapy, Molecular therapy, *In-vitro* organogenesis, treatments, Gene therapy and tissue-engineered physiological models

References

1. Bikramijit Basu., *Biomaterials Science and Tissue Engineering: Principles and Methods*, 1st Ed., Cambridge University Press, 2017 .
2. Robert A Brown, *Extreme Tissue Engineering: Concepts and Strategies for Tissue Fabrication*, Wiley Blackwell, 2013.
3. Lanza R, Weissman I, Thomson J, and Pedersen R, *Handbook of Stem Cells*, 2nd Ed., Academic Press, 2012.

BIT3243 Stem Cell Technology [3-0-0-3]

Introduction to stem cells, their properties and types, regulators of Pluripotency and Differentiation of Stem Cell, Differences between Adult and Embryonic Stem Cells, stem cells and their potential sources Isolation and culture techniques for stem cells, Stem cells engineering and applications in therapy, Case study on cardiac repair using iPS. Case study on successful treatment of disease by using stem cells.Ethical concerns and controversy for stem cell research.

References

1. S. Sell, Stem *cells handbook*, Totowa, NJ: Humana Press,2004.
2. R.L. Gardner, D.I. Gottlieb, and D.R. Marshak, *Stem cell biology*, Cold Spring Harbor Laboratory Press, 2001.
3. F. Robert Almeder, *Stem cell research*, Humana Press–2004.
4. Chiu, Arlene Y, and Mahendra S. Rao, *Human embryonic stem cells*, Totowa, NJ: Humana Press, 2003.

BIT3270 Project Based Learning 4 [0-0-6-3]

Project Based Learning will be a practical study in the emerging areas of biotechnology

B.Tech. (Biotechnology) VI Semester Lab Experiments

BIT3230 Immunology Lab [0-0-4-2]

1. Separation of Serum and Plasma from Blood

2. Cell Counting using Haemocytometer– RBC and WBC

3. Differential leukocyte count by Leishmann's staining

4. Identification of blood group and Rh typing

5. Testing for typhoid antigens by Widal test

6. Testing for Anti streptolysin– O

7. Single Radial Immunodiffusion

8. Immunodiffusion – Ouchterlony Double Diffusion

9. Immunoelectrophoresis – Rocket immunoelectrophoresis

10. Enzyme-Linked Immunosorbent Assay (ELISA)

11. Agglutination Assay using Antibodies and Antigens

12. Antigen-antibody Precipitation Reactions in Agar Gel

13. Complement Fixation Test (Demonstration)

14. Total Immunoglobulin Estimation

15. Detection of C-reactive Protein (CRP)

SEVENTH SEMESTER

Program Elective 7

BIT4141 Animal and Plant Biotechnology [3-0-0-3]

Culture media composition and growth conditions; Animal cell and tissue preservation; Anchorage and non-anchorage dependent cell culture; Kinetics of cell growth; Micro & macro-carrier culture; Hybridoma technology; Stem cell technology; Animal cloning; Transgenic animals; Knock-out and knock-in animals.

Totipotency; Regeneration of plants; Plant growth regulators and elicitors; Tissue culture and cell suspension culture system - methodology, kinetics of growth and nutrient optimization; Production of secondary metabolites; Hairy root culture; Plant products of industrial importance; Artificial seeds; Somaclonal variation; Protoplast, protoplast fusion - somatic hybrid and cybrid; Transgenic plants - direct and indirect methods of gene transfer techniques; Selection marker and reporter gene; Plastid transformation.

References

7. Glick, B. R., Pasternak, J. J., & Patten, C. L. (2022). *Molecular biotechnology: Principles and applications of recombinant DNA* (6th ed.). ASM Press.
8. Freshney, R. I. (2016). *Culture of animal cells: A manual of basic technique* (7th ed.). Wiley-Liss.
9. Slater, A., Scott, N. W., & Fowler, M. R. (2008). *Plant biotechnology: The genetic manipulation of plants* (3rd ed.). Oxford University Press.
10. Brown, T. A. (2020). *Gene cloning and DNA analysis: An introduction* (8th ed.). John Wiley & Sons.
11. Moo-Young, M. (Ed.). (2019). *Comprehensive biotechnology* (3rd ed.). Elsevier.

Sambrook, J., & Russell, D. W. (2001). *Molecular cloning: A laboratory manual* (3rd ed.). Cold Spring Harbor Laboratory Press.

BIT4142 Molecular Diagnostics [3-0-0-3]

Introduction, specimen types and uses, types of molecular diagnostics, Enzyme Immunoassays: Comparison of enzymes available for enzyme immunoassays, conjugation of enzymes. Solid phases used in enzyme immunoassays, Homogeneous and heterogeneous enzyme immunoassays, Enzyme immunoassays after immuno blotting, Enzyme immuno histochemical techniques: Use of polyclonal or monoclonal antibodies, diagnostic microbiology, Molecular methods in clinical microbiology, Laboratory tests in chemotherapy: Susceptibility tests, diffusion test procedures, Tests for bactericidal activity and automated procedures for antimicrobial susceptibility tests, Automation and rapid diagnostic approach: Automation in microbial diagnosis, rapid diagnostic approach, Idiotypes and immunodiagnostic: Concepts and methods in idiotypes, Anti-idiotypes and molecular mimicry and receptors, Epitope design and applications, Immunodiagnostic tests, Diagnostic tools.

References

1. D. E. Bruns, E. R. Ashwood, and C. A. Burtis, *Fundamentals of Molecular Diagnostics*, 2nd ed. St. Louis, MO: Elsevier Health Sciences, 2015.

2. L. Buckingham and M. L. Flaws, *Molecular Diagnostics: Fundamentals, Methods and Clinical Applications*, 2nd ed. Philadelphia, PA: F. A. Davis Company, 2019.
3. W. B. Coleman and G. J. Tsongalis, *Molecular Diagnostics for the Clinical Laboratorian*, 3rd ed. New York, NY: Humana Press, 2016.

BIT4143 Bioreactor design and Analysis [3-0-0-3]

Introduction to Bioreactors- classification of bioreactors based on factors like oxygen availability, mode of operation, and type of biological agent - Components of a bioreactor and their functions (vessel, impeller, sparger, baffles, etc.) - bioreactor Operation and scale-up - Bioreactor Design Principles - Case Studies and Applications - Specific bioreactor designs for different applications (e.g., microbial fermentation, cell culture) - analysis of bioreactor performance - Optimization of bioreactor operation for productivity and cost-effectiveness -bioreactor control systems and automation.

References

1. J. M. Doran, *Bioprocess Engineering Principles*, 2nd ed. Cambridge, MA, USA: Academic Press, 2013.
2. P. M. Doran, *Principles of Fermentation Technology*, 3rd ed. Oxford, U.K.: Butterworth-Heinemann, 2020.
3. M. L. Shuler and F. Kargi, *Bioprocess Engineering: Basic Concepts*, 2nd ed. Upper Saddle River, NJ, USA: Prentice Hall, 2017.
4. A. L. Demain and J. E. Davies, *Manual of Industrial Microbiology and Biotechnology*, 3rd ed. Washington, DC, USA: ASM Press, 2010.
5. H. C. Vogel and C. D. Todaro, *Fermentation and Biochemical Engineering Handbook*, 3rd ed. Norwich, NY, USA: William Andrew Publishing, 2014.

BIT4144 Biotherapeutics [3-0-0-3]

Definition and scope of biotherapeutics, Historical perspective and evolution of biopharmaceuticals, Comparison of small molecules vs. biologics, Overview of different classes of biotherapeutics: proteins, peptides, antibodies, vaccines, gene therapy, cell therapy, nucleic acid therapeutics, Therapeutic antibodies, Monoclonal antibody technology: Hybridoma technology, phage display, Antibody engineering: Chimeric, humanized, and fully human antibodies, Clinical applications of therapeutic antibodies in cancer, autoimmune diseases, and infectious diseases, Gene therapy: Principles of gene therapy: Gene augmentation, gene silencing, gene editing (CRISPR/Cas9), Viral vectors (Adenovirus, AAV, Lentivirus) and non-viral vectors for gene delivery, Stem cell-based therapies: Embryonic stem cells, induced pluripotent stem cells (iPSCs), mesenchymal stem cells (MSCs), CAR T-cell therapy: Design, production, and clinical applications in oncology, Quality Control (QC) of Biotherapeutics, Regulatory Affairs: Good Manufacturing Practices (GMP), Good Laboratory Practices (GLP), Good Clinical Practices (GCP), Regulatory agencies (e.g., FDA, EMA, CDSCO), IND (Investigational New Drug) and BLA (Biologics License Application) processes, Biosimilars and biobetters, Clinical trials design and phases for biotherapeutics, Ethical considerations and IPR in biotherapeutics development.

References

1. J. A. L. Murray, *Therapeutic Proteins: Methods and Protocols*, 3rd ed. New York, NY, USA: Humana Press, 2017.
2. G. Walsh, *Pharmaceutical Biotechnology: Concepts and Applications*, 3rd ed. Chichester, UK: Wiley-Blackwell, 2014.

Program Elective 8

BIT4145 Bioethics and Biosafety [3-0-0-03]

BIOETHICS: Principles of bioethics, bioethics vs. business ethics, ethical dimensions of IPR, technology transfer and other global biotech issues. The legal, institutional and socioeconomic impacts of biotechnology; Awareness of bioethics about generating new forms of life for informed decision making – with case studies. Ethical conflicts in biotechnology, Rational vs. subjective perceptions of risks and benefits, relationship between risk, hazard, exposure and safeguards, Biotechnology and biosafety concerns at the level of individuals, institutions, society, region, country and the world. The Cartagena protocol on biosafety. Biosafety management. Ethical implications of biotechnological products and techniques. Regulations: Biosafety assessment procedures in India and abroad. International dimensions in biosafety, bioterrorism and convention on biological weapons. Social and ethical implications of biological weapons. Biosafety regulations and national and international guidelines regarding recombinant DNA technology and transgenic plants. Good manufacturing practice and Good lab practices. National and international regulations for food and pharma products. IPR, PATENTS AND PATENT LAWS. Biodiversity and farmer rights. Objectives, system, Basic principles and general requirements of patent law. The patenting of living organisms

References

1. M. K. Sateesh, *Bioethics and Biosafety*, 2nd ed. New Delhi, India: IK International Publishing House Pvt Ltd, 2017.
2. D. O. Fleming and D. L. Hunt, *Biological Safety: Principles and Practices*, 4th ed. Washington, DC: ASM Press, 2006.

BIT4146 Entrepreneurship in Biotechnology [3-0-0-3]

Entrepreneurship: Concept and theories of Entrepreneurship, Entrepreneurial traits and motivation, Nature and importance of Entrepreneurs, types of Entrepreneurships, stages in the entrepreneurial process. Bio-innovation to bio-business case studies from Indian context; Indian Company act for Bio business; Regulatory affairs and Regulatory bodies (FDA, DSIR, AYUSH, FSSAI). Profiling the Bioentrepreneur; Entrepreneurial Opportunity; Entrepreneurial Planning; Commercialization Process & Strategy; Management of Intellectual Property Rights; Financial Management; Financial Statements; Human Resource Management; Marketing Strategy; Strategies for Partnering & Collaboration; Negotiation Skills; Managing Regulatory Requirements; Funding Opportunities & Incentives; Government Initiatives for Startups; Preparing Business Plan.

References

1. D. Hine and J. Kapeleris, Innovation and Entrepreneurship in Biotechnology, An International Perspective, 1st ed. Edward Elgar Publishing, 2006.

2. M. V. Jones, C. Wheeler, and P. Dimitratos, International Entrepreneurship in the Life Sciences, 1st ed. Edward Elgar Publishing, 2011.
3. F. Mermelstein, R. Prince, and C. Novina, Biotechnology from Idea to Market, 1st ed. Bethesda, MD: Pda; River Grove, IL, 2019.
4. J. Watal, Intellectual Property Rights in the WTO and Developing Countries, 1st ed. Springer, 2001.

BIT4147 Renewable energy and sustainable engineering [3-0-0-3]

Introduction to Energy and Sustainability, Global energy demand and sources, Principles of sustainable development, Energy Efficiency and Conservation in industry, buildings, and transportation, Solar Energy – Thermal Systems, Solar thermal collectors and applications Solar water heaters and concentrating solar power (CSP), Photovoltaic Systems (PV) principles and materials, Wind Energy- Wind resource assessment, Wind turbine types, operation, and siting. Hydropower Run-of-river and reservoir systems, Small and micro hydropower, Environmental impacts and mitigation. Biomass and Bioenergy- Biomass resources and conversion technologies. Biofuels: ethanol, biodiesel, biogas. Sustainability concerns. Energy Storage Systems- Batteries, flywheels, supercapacitors, Hydrogen and fuel cells, Pumped hydro and thermal storage. Sustainable Building Design- Passive solar design, green building materials. Environmental Impact and Policy, Emissions and carbon footprint, LEED/BREEAM certifications, Environmental regulations and energy policy, IPCC reports, Paris Agreement. Case Studies and Emerging Trends.

References

1. G. Boyle, *Renewable Energy: Power for a Sustainable Future*, 5th ed. Oxford, U.K.: Oxford Univ. Press, 2021.
2. J. W. Tester, E. M. Drake, M. J. Driscoll, M. W. Golay, and W. A. Peters, *Sustainable Energy: Choosing Among Options*, 3rd ed. Cambridge, MA, USA: MIT Press, 2021.
3. S. A. Kalogirou, *Solar Energy Engineering: Processes and Systems*, 2nd ed. Amsterdam, Netherlands: Academic Press, 2013.
4. C. J. Kibert, *Sustainable Construction: Green Building Design and Delivery*, 5th ed. Hoboken, NJ, USA: Wiley, 2022.