Course Code	Course Name	L-T-P	Credits	Year of Introduction
BT302	Transport Phenomena in Biological Systems	4-0-0	4	2016

Prerequisite: Nil

Course Objectives:

- To enable students to apply fundamental knowledge about Heat, Mass and Momentum Transfer in real time problems
- To provide knowledge on application of transport operations.
- To familiarize the students about various boundary conditions in heat, mass and momentum transport.
- To provide knowledge and training to students to apply basic equations of change from heat, mass and momentum transport to solve problems.

Syllabus

Introduction to Momentum, Heat and Mass Transport, Shell momentum balances and boundary conditions for momentum, heat and mass transport, Theories on viscosity of gases and liquids(Including Numerical Examples)- Theories on thermal conductivity of gases and liquids(Including Numerical Examples)- Theories on diffusion in gases and liquids(Including Numerical Examples), Analogies between Heat, mass and Momentum Transfer, General transport equations for momentum- Application of transport equations to solve steady flow problems.

Expected outcome

Upon successful completion of the course the student will be able to

i. Differentiate Newtonian and Non-Newtonian fluids with suitable examples.
ii. Calculate the transport properties of gases and liquids.
iii. Solve problems in momentum, heat and mass transfer through shell balance.
iv. Apply suitable boundary conditions to solve shell balance equations.
v. Apply transport equations to solve steady flow and heat transfer problems.

Reference Books

1. Bird R B, Stewart W E and Lightfoot R N, Transport Phenomena, John Wiley and Sons.
2. John C Slattery, Momentum, Energy and Mass transfer in continua, McGraw Hill, Co.
3. Bennet C U and Myers J E, Momentum, Heat and Mass Transfer, Tata McGraw Hill Publishing Co.
4. Robert S. Brodkey and Harry C Hersing, Transport Phenomena a Unified Approach, McGraw Hill.
5. Atkinson B and Mavituna F, Biochemical Engineering and Biotechnology, Handbook, Macmillan

Note: The students may be permitted to use attested copies of tables of general equations of continuity, motion and energy in Cartesian, rectangular and curvilinear coordinates, and Fluid Properties Tables inside the examination hall.

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	**Introduction to Momentum Transport**: Newton's Law of viscosity-Non-Newtonian Fluid Models-Pressure and Temperature dependency of viscosity. **Introduction to Heat Transport**: Fourier's Law – Newton's Law of cooling-Temperature and pressure dependency of	9	15%

	thermal conductivity. **Introduction to Mass Transport:** Fick's Law of binary diffusion- Temperature and pressure dependency of diffusivity.(Only a brief overview is needed)Shell momentum balances and boundary conditions for momentum, heat and mass transport.		
II	**Molecular theory of viscosity of gases** at low density-**Molecular theory of viscosity of liquids**-Calculation of viscosity of gas mixture-Numerical examples. Theory of thermal conductivity of gases at low density-Theory of thermal conductivity of liquids and solids-Numerical Examples	9	15%
FIRST INTERNAL EXAM			
III	**Theory of diffusion in gases** at low density-Theory of Diffusion in binary liquids-Numerical Examples. Definitions of various concentration terms, velocities, Mass and Molar fluxes-Notations and relationships for various Mass and molar fluxes. Analogies between Heat mass and Momentum Transfer.	8	15%
IV	**Velocity distribution in laminar flow:** Flow of a falling film-flow through a vertical circular tube-flow through an annulus-adjacent flow of two immiscible fluids. **General transport equations for momentum:** derivation of continuity equation- Analysis of equation of motion in rectangular coordinates (derivation not desired)-Navier Stoke's equation and Euler equation with significance of each terms(derivation not desired)- transport equation in curvilinear coordinates (derivation not desired). **Application of transport equations to solve steady flow problems:**- flow through a tube- tangential annular flow.	10	15%
SECOND INTERNAL EXAM			
V	**Application of shell balances to heat conduction problems:-** With electric, nuclear & viscous heat sources-cooling fins with insulated tip condition. **Equations of energy:-** energy equation in rectangular coordinates-energy equations in curvilinear coordinates (derivation not desired) **Application of transport equations to solve steady heat transfer problems:-** tangential flow in annulus with viscous heat generation- free convection from vertical plate.	10	20%
VI	**Shell mass balances:** diffusion through a stagnant gas film-diffusion with heterogeneous chemical reaction(for slow and instantaneous reactions)- diffusion with homogeneous chemical reaction- diffusion through a spherical stagnant gas film surrounding a droplet of liquid- diffusion and chemical reaction inside a porous catalyst: the effectiveness factor-General study equation of continuity for binary mixtures in rectangular coordinates (derivation not desired)-equation of continuity in curvilinear coordinates (derivation not desired).	10	20%
END SEMESTER EXAMINATION			

QUESTION PAPER PATTERN:

Maximum Marks: 100 Exam Duration: 3 hours

The question paper consists of Part A, Part B and Part C.

Part A consists of three questions of 15 marks each uniformly covering Modules I and II. The student has to answer two questions (15×2=30 marks).

Part B consists of three questions of 15 marks each uniformly covering Modules III and IV. The student has to answer two questions (15×2=30 marks).

Part C consists of three questions of 20 marks each uniformly covering Modules V and VI. The student has to answer two questions (20×2=40 marks).

For each question there can be a maximum of 4 subparts.

Course Code	Course Name	L-T-P	Credits	Year of Introduction
BT304	**Downstream processing**	**3-0-0**	**3**	**2016**

Prerequisite: Nil

Course Objectives:

- To study the characteristics of biomolecules and types of cell disruption methods.
- To study the principles of solid liquid separation processes filtration and centrifugation.
- To study the principles of Adsorption, Extraction, membrane separation and Precipitation.
- To study the principle of crystallization, drying and lyophilisation.

Syllabus

Overview of bioseparations, cell disruption and cell separation, principles, process, equipment and applications of general product recovery operations, product purification and drying.

Expected outcome

After successful completion of the course, the students would have learnt

i. Strategies of downstream processing based on characteristics of biomolecules.
ii. Various cell disruption techniques.
iii. Insolubles removal and predict operating optimal parameters for large scale operations.
iv. Techniques of bulk product / protein isolation and purification.
v. To design purification strategy based on product characteristics and cost effectiveness.

Reference Books

1. Paul A Belter, EL Cussler, Wei-shou Hu, *Bioseparations: Downstream Processing for Biotechnology* - Wiley Interscience, 1988.
2. Harrison RG, Todd P, Rudge SR, Petrides DP, *Bioseparations Science and Engineering*, Oxford Press, 2003.
3. Sivasankar B, *Bioseparations: Principles and Techniques*, Prentice-Hall of India Pvt. Ltd., 2008.
4. Richard W Baker, *Membrane Technology and applications*, John Wiley & Sons Ltd., 2004.
5. McCabe, WL, Smith JC, Harriott P, *Unit Operation of Chemical Engineering*, 6/e, McGraw Hill, New York, 2000.

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	***Overview of bioseparations***: Broad classification of bioproducts, characteristics of fermentation broths, spectrum of bioseparations, need for downstream processing, criteria for choice of recovery processes, synthesis of bioseparation processes, problems and requirements of bioproduct purification, properties of biomolecules. ***Cell disruption***: Analysis of various physical, chemical, enzymatic and mechanical methods for release of intracellular products- kinetics of bead milling and high pressure homogenization- maintenance of activity of intracellular proteins- during cell lysis.	5	15%
II	***Flocculation***: Importance in downstream processing, electrical double layer concept, DLVO theory, mechanisms of charge dependent flocculation.	5	15%

	Foam and bubble fractionation: Principle and operation-applications ***Gravity sedimentation***: Mechanisms of sedimentation, Design of industrial equipments for gravity settling-thickeners, classifiers. – applications in downstream processing		
	FIRST INTERNAL EXAM		
III	***Centrifugal bioseparations***: Theory of centrifugal settling-basic equations, Sedimentation coefficient, production centrifuges, centrifuge selection-RCF, scale up of centrifuges-sigma analysis, equivalent time- Isopycnic sedimentation, ultra centrifugation. ***Filtration***: Equipments for conventional filtration- filter media, pretreatment methods, general filtration theory-Darcy's law, compressible and incompressible filter cakes, filtration cycle, scale up and design of filtration systems laboratory filtration tests- batch pretreatment test, funnel filtration tests, filter leaf tests.	8	15%
IV	***Extractive bioseparations***: General principles, analysis of batch and staged extraction - analytical and graphical methods, differential and fractional extraction-scale up and design of extractors- reciprocating plate extraction columns, centrifugal extractors- aqueous two phase extraction, reversed micellar extraction and supercritical fluid extraction theoretical principles, process, equipment and applications. ***Precipitation***: Factors influencing protein solubility, methods of precipitation, precipitate formation phenomena orthokinetic and perikinetic aggregation- Smoluchowski's equation-precipitate ageing- Camp number- design of precipitation systems.	8	15%
	SECOND INTERNAL EXAM		
V	***Membrane separation processes***: Crossflow filtration – filter media- ultra filtration and microfiltration membranes, filter modules, modes of operation, concentration polarization and fouling-reverse osmosis, dialysis, electrodialysis, pervaporation, perstraction. ***Chromatographic separations*****:** Classification of techniques, elution chromatography- retention theory, band broadening effects, separation efficiency, resolution, yield and purity, discrete stage analysis, kinetic analysis-Gas and liquid chromatography- Bonded phase chromatography, Ion exchange chromatography, gel permeation chromatography, affinity chromatography- supercritical fluid chromatography – Chiral chromatography- expanded bed chromatography-simulated countercurrent chromatography- process scale up. ***Electrokinetic separations***: Electrophoresis – Principles and techniques- immunoelectrophoresis, capillary zone electrophoresis - isoelectric focusing, isotachophoresis.	8	20%

VI	***Product crystallization***: Basic principles- nucleation and crystal growth- Mier's supersaturation theory- kinetics of crystallization-analysis of dilution batch crystallization- commercial crystallizers- process crystallization of proteins scale up and design of crystallizers- Recrystallization. ***Product drying***: Heat and mass transfer in drying- types of commercial dryers- vacuum dryers, freeze dryers, spray dryers- scale up and design of drying systems. ***Modern strategies***: Bioprocess integration, intensification, *in situ* bioproduct recovery, combined operations- whole broth processing, mass recycle.	8	20%
END SEMESTER EXAMINATION			

QUESTION PAPER PATTERN:

Maximum Marks: 100 Exam Duration: 3 hours

The question paper consists of Part A, Part B and Part C.

Part A consists of three questions of 15 marks each uniformly covering Modules I and II. The student has to answer two questions (15×2=30 marks).

Part B consists of three questions of 15 marks each uniformly covering Modules III and IV. The student has to answer two questions (15×2=30 marks).

Part C consists of three questions of 20 marks each uniformly covering Modules V and VI. The student has to answer two questions (20×2=40 marks).

For each question there can be a maximum of 4 subparts.

Course Code	Course Name	L-T-P	Credits	Year of Introduction
BT306	Bioprocess Engineering	3-0-0	3	2016

Prerequisite: Nil

Course Objectives

- To introduce students to some of the important aspects of industrial bioprocessing.
- To highlight the importance of modelling in bioprocess optimisation and scale-up of bioprocesses.

Syllabus

Isolation, preservation, and improvement of industrial microorganisms, general requirements of a fermentation process, inoculum development and maintenance, medium and air sterilisation, metabolic stoichiometry and energetics, modelling and optimisation, scale-up of bioreactors.

Expected outcome

After successful completion of the course, the students will be able to

i. Describe isolation and preservation of microorganisms.
ii. Explain inoculum development and maintenance.
iii. Describe medium and air sterilisation methods.
iv. Carry out elemental balances and calculate degree of reductance.
v. Explain bioreactor scale-up and sale-down procedures.

Reference Books

1. Brian McNeil, Linda Harvey (Eds.), *Practical Fermentation Technology*, Wiley, 2008.
2. Rajiv Dutta, *Fundamentals of Biochemical Engineering*, Springer, 2008.
3. Michael C Flickinge (Ed.), *Upstream Industrial Biotechnology*, Volumes 1 & 2, Wiley 2013.
4. Pauline M Doran, *Bioprocess Engineering Principles*, Academic press, 1995.
5. J E Bailey, D F Ollis, *Biochemical Engineering Fundamentals*, 2/e, McGraw-Hill Chemical Engineering Series, 1986.
6. Michael L Shuler, Fikret Kargi, *Bioprocess Engineering Basic Concepts*, Prentice Hall, 1992.

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	Isolation, preservation, and improvement of industrially important microorganisms - isolation of microorganisms of potential interest, enrichment culture, screening methods, culture preservation, strain improvement: mutagenesis, protoplast fusion and r-DNA technology, culture collection and biological resource centres.	6	15%
II	General requirements of a fermentation process, classification of fermentation processes, industrial microorganisms - wild and specific microorganisms, GRAS microorganisms, characteristics of good industrial microorganisms, inoculum, processes requiring monoculture inoculum and mixed culture inoculum, inoculum development and maintenance, effect of age/size of inoculum on cell growth and product formation, cell viability measurements.	6	15%
FIRST INTERNAL EXAM			

III	Medium & air sterilisation methods, del factor, batch & continuous sterilisation, in-situ sterilization in fermenter, thermal death kinetics of cells and spores, extinction probability, batch and continuous steriliser design aspects, sterilisation of liquid wastes, air sterilisation-design of fibrous type filters.	7	15%
IV	Metabolic stoichiometry and energetics - Stoichiometry of cell growth and product formation, elemental balances, degrees of reduction of substrate and biomass, available electron balances, yield coefficient of biomass and product formation, maintenance coefficients, energetics analysis of microbial growth and product formation, oxygen consumption and heat evolution in aerobic cultures, thermodynamic efficiency of growth, volumetric and specific rates for basic microbial activities.	8	15%
SECOND INTERNAL EXAM			
V	Modelling and optimisation of bioprocesses-definition of a model, need for modelling and control in bioprocesses, steps in model building, various models for cell kinetics-structured, unstructured, segregated and unsegregated models, Monod and Leudeking-Piret models, state variables (cell growth, substrate consumption or product formation, intracellular components),parameter estimation, optimisation criteria, model fitting and validation.	8	20%
VI	Scale-up and scale-down of bioreactors, correlations for oxygen transfer, effect of sale on oxygenation, mixing, bioreactor scale-up based on constant power consumption per volume, mixing time, impeller tip speed (shear), mass transfer coefficients, regime analysis of bioreactor processes.	7	20%
END SEMESTER EXAMINATION			

QUESTION PAPER PATTERN:

Maximum Marks: 100 Exam Duration: 3 hours

The question paper consists of Part A, Part B and Part C.

Part A consists of three questions of 15 marks each uniformly covering Modules I and II. The student has to answer two questions (15×2=30 marks).

Part B consists of three questions of 15 marks each uniformly covering Modules III and IV. The student has to answer two questions (15×2=30 marks).

Part C consists of three questions of 20 marks each uniformly covering Modules V and VI. The student has to answer two questions (20×2=40 marks).

For each question there can be a maximum of 4 subparts.

Course Code	Course Name	L-T-P	Credits	Year of Introduction
BT308	**Bioreactor Analysis and Design**	**3-0-0**	**3**	**2016**

Prerequisite: Nil

Course Objectives

- To introduce the state of the arts in bioreactor technology and its broad range of applications
- To strengthen the knowledge on analysing bioreactor performance.

Syllabus

Function, description, working, advantages and limitations of various bioreactors, batch bioreactors, Ideal continuous flow stirred tank bioreactors, plug flow tubular reactors, design aspects of bioreactors, non-ideal reactors.

Expected outcome

Upon successful completion of the course, the students will be able to

i. Explain how different bioreactors work.
ii. Calculate batch reaction time.
iii. Estimate substrate conversion and biomass productivity in a chemostat.
iv. Calculate reactor length and residence time.
v. Describe the design aspects of bioreactors.

Reference Books

1. Tapobrata Panda, *Bioreactors: Analysis and Design*, Tata McGraw-Hill Education, 2011.
2. Pauline M Doran, *Bioprocess Engineering Principles*, Academic Press, 2013.
3. Alan H Scragg, *Bioreactors in Biotechnology - A Practical Approach*, Ellis Horwood, 1991.
4. Klaas van't Riet, Johannes Tramper, *Basic Bioreactor Design*, Marcel Dekker, 1991.
5. Douglas S Clark, Harvey W Blanch, *Biochemical Engineering*, 2/e, Marcel Dekker, 1997.

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	Bioreactors - Function, description, working, advantages and limitations of stirred tank, airlift, airlift pressure cycle bioreactor, packed bed, fluidized bed, trickle bed and flocculated cell bioreactors. Novel Bioreactors - inverse fluid flow units, hollow fibre reactors, centrifugal field reactors, rotating drum bioreactor, spin filter bioreactor, disposable culture systems and wave bioreactor.	7	15%
II	Batch bioreactor, cell death in batch reactor, endogenous metabolism, maintenance, calculation of batch reaction time from ideal system for enzyme reaction and cell culture, batch reaction time with enzyme deactivation, calculation of total batch time.	7	15%
FIRST INTERNAL EXAM			
III	Ideal continuous flow stirred tank bioreactor(CFSTBR) - chemostat, multiple steady state analysis, steady state concentrations in a chemostat, substrate conversion and	8	15%

	biomass productivity, mean residence time, comparison of batch bioreactor and single stage CFSTBR, washout condition, stability of the chemostat, chemostat with cell recycle, comparison of steady-state biomass concentration and volumetric biomass productivity for a chemostat with and without cell recycle, numerical problems on conversion and productivity.		
IV	Plug flow tubular reactor (PFTR), comparison of ideal mixed flow (batch and CFSTBR) and plug flow tubular reactors, calculation of reactor length and residence time, recycling in PFTRs, analysis of recycle reactors.	5	15%
SECOND INTERNAL EXAM			
V	Design aspects of bioreactors, bioreactor geometry, guidelines for bioreactor design, bioreactor vessels, agitator assembly, mass transfer aspects, rheology and mixing, design, operation and types of agitators, power requirements for agitation, effects of agitation on mass transfer, oxygen delivery system - spargers, foam control system, factors affecting antifoam requirements, mass transfer between phases – factors affecting mass transfer between phases, oxygen uptake in fermenters.	8	20%
VI	Concept of non-ideal reactors, residence time distribution, E(t) or F(t) and the bioreactor design, models of non-ideal reactors - plug flow with axial dispersion, tanks-in-series model, drawbacks of classical RTD measurements, stability analysis of microbial reactors, transient behavior in bioreactor.	7	20%
END SEMESTER EXAMINATION			

QUESTION PAPER PATTERN:

Maximum Marks: 100 Exam Duration: 3 hours

The question paper consists of Part A, Part B and Part C.

Part A consists of three questions of 15 marks each uniformly covering Modules I and II. The student has to answer two questions (15×2=30 marks).

Part B consists of three questions of 15 marks each uniformly covering Modules III and IV. The student has to answer two questions (15×2=30 marks).

Part C consists of three questions of 20 marks each uniformly covering Modules V and VI. The student has to answer two questions (20×2=40 marks).

For each question there can be a maximum of 4 subparts. .

Course code	Course Name	L-T-P - Credits	Year of Introduction
HS300	Principles of Management	3-0-0-3	2016

Prerequisite : Nil

Course Objectives

- To develop ability to critically analyse and evaluate a variety of management practices in the contemporary context;
- To understand and apply a variety of management and organisational theories in practice;
- To be able to mirror existing practices or to generate their own innovative management competencies, required for today's complex and global workplace;
- To be able to critically reflect on ethical theories and social responsibility ideologies to create sustainable organisations.

Syllabus

Definition, roles and functions of a manager, management and its science and art perspectives, management challenges and the concepts like, competitive advantage, entrepreneurship and innovation. Early contributors and their contributions to the field of management. Corporate Social Responsibility. Planning, Organizing, Staffing and HRD functions, Leading and Controlling. Decision making under certainty, uncertainty and risk, creative process and innovation involved in decision making.

Expected outcome.

A student who has undergone this course would be able to

i. manage people and organisations
ii. critically analyse and evaluate management theories and practices
iii. plan and make decisions for organisations
iv. do staffing and related HRD functions

Text Book:

Harold Koontz and Heinz Weihrich, *Essentials of Management*, McGraw Hill Companies, 10th Edition.

References:

1. Daft, *New era Management*, 11th Edition, Cengage Learning
2. Griffin, *Management Principles and Applications*, 10th Edition, Cengage Learning
3. Heinz Weirich, Mark V Cannice and Harold Koontz, *Management: a Global, Innovative and Entrepreneurial Perspective*, McGraw Hill Education, 14th Edition
4. Peter F Drucker, *The Practice of Management*, McGraw Hill, New York
5. Robbins and Coulter, *Management*, 13th Edition, 2016, Pearson Education

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	Introduction to Management: definitions, managerial roles and functions; Science or Art perspectives- External environment-global, innovative and entrepreneurial perspectives of Management (3 Hrs.)– Managing people and organizations in the context of New Era- Managing for competitive advantage - the Challenges of Management (3 Hrs.)	6	15%

II	**Early Contributions and Ethics in Management**: Scientific Management- contributions of Taylor, Gilbreths, Human Relations approach-contributions of Mayo, McGregor's Theory, Ouchi's Theory Z (3 Hrs.) Systems Approach, the Contingency Approach, the Mckinsey 7-S Framework Corporate Social responsibility- Managerial Ethics. (3 Hrs)	6	15%
FIRST INTERNAL EXAMINATION			
III	**Planning:** Nature and importance of planning, -types of plans (3 Hrs.)- Steps in planning, Levels of planning - The Planning Process. – MBO (3 Hrs.).	6	15%
IV	**Organising for decision making:** Nature of organizing, organization levels and span of control in management Organisational design and structure –departmentation, line and staff concepts (3 Hrs.) Limitations of decision making- Evaluation and selecting from alternatives- programmed and non programmed decisions - decision under certainty, uncertainty and risk-creative process and innovation (3 Hrs.)	6	15%
SECOND INTERNAL EXAMINATION			
V	**Staffing and related HRD Functions:** definition, Empowerment, staff – delegation, decentralization and recentralisation of authority – Effective Organizing and culture-responsive organizations –Global and entrepreneurial organizing (3 Hrs.) Manager inventory chart-matching person with the job-system approach to selection (3 Hrs.) Job design-skills and personal characteristics needed in managers-selection process, techniques and instruments (3 Hrs.)	9	20%
VI	**Leading and Controlling:** Leading Vs Managing – Trait approach and Contingency approaches to leadership - Dimensions of Leadership (3 Hrs.) - Leadership Behavior and styles – Transactional and Transformational Leadership (3 Hrs.) Basic control process- control as a feedback system – Feed Forward Control – Requirements for effective control – control techniques – Overall controls and preventive controls – Global controlling (3 Hrs.)	9	20%
END SEMESTER EXAM			

Question Paper Pattern

Max. marks: 100, Time: 3 hours .
The question paper shall consist of three parts

Part A: 4 questions uniformly covering modules I and II. Each question carries 10 marks
Students will have to answer any three questions out of 4 (3X10 marks =30 marks)
Part B : 4 questions uniformly covering modules III and IV. Each question carries 10 marks
Students will have to answer any three questions out of 4 (3X10 marks =30 marks)
Part C: 6 questions uniformly covering modules V and VI. Each question carries 10 marks
Students will have to answer any four questions out of 6 (4X10 marks =40 marks)

Note: In all parts, each question can have a maximum of four sub questions, if needed.

Course Code	Course Name	L-T-P	Credits	Year of Introduction
BT362	Sustainable Energy Processes	3-0-0	3	2016

Prerequisite: Nil

Course Objectives

- To introduce the current and potential future energy systems, covering resources, extraction, conversion, and applications, with emphasis on meeting regional and global energy needs in a sustainable manner.

Syllabus

Classification of energy, extraction, conversion, and applications of solar energy, wind energy, ocean energy, biomass energy, fuel cells and hydro-dynamic systems, merits and demerits of various energy systems, energy storage.

Expected outcome

Students who successfully complete this course should be able to

i. Identify global and Indian energy sources.
ii. Explain capture, conversion and application of solar and wind energy.
iii. Explain conversion of biomass to energy.
iv. Explain the capture of energy from oceans.
v. Explain fuel cells and energy storage routes.

Reference Books

1. Bansal N K, Kleemann M, Michael Meliss, *Renewable Energy Sources & Conversion Technology*, Tata McGraw Hill publishing Company, New Delhi, 1990.
2. Boyle, Godfrey, *Renewable Energy*, 3/e, Oxford University Press, 2012.
3. S P Sukhatme, *Solar Energy - Principles of Thermal Collection and Storage*, 2/e, Tata McGraw- Hill Publishing company, New Delhi,1996.
4. Pramod Jain, *Wind Energy Engineering*, McGraw Hill, 2011.
5. Donald L Klass, *Biomass for Renewable Energy, Fuels and Chemicals*, Academic Press, 1998.

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	**General classification of energy**. Conventional and non-conventional. Renewable and non-renewable. Global and Indian energy sources. Global and Indian energy consumption. Problems of fossil fuels. Environmental aspects of energy utilization. Energy and sustainable development. Energy planning. Renewable energy sources, potentials, achievements and applications.	7	15%
II	**Solar energy**. Solar radiation. Solar thermal systems. Flat plate and concentrating collectors. Solar desalination. Solar pond. Solar cookers. Solar dryers. Solar thermal electric power plant. Solar photovoltaic conversion. Semiconductor and thin film technology. Solar cells. Solar photovoltaic power generation. Hybrid systems. Merits and limitations of solar energy.	7	15%
FIRST INTERNAL EXAM			

III	**Wind energy**. Availability of wind energy, Site characteristics, Wind turbine types-horizontal axis and vertical axis-design principles of wind turbine. Wind power plants, Wind energy storage. Safety and environmental aspects. Merits and limitations of wind energy.	7	15%
IV	**Biomass energy**. Biomass resources, Biomass conversion technologies-direct combustion, pyrolysis, biomass gasification. Biogas production. Biomethanation as an aid to environment improvement. Bioethanol, biodiesel and biobutanol production. Hydrogen as fuel. Biohydrogen production. Storage of hydrogen.	7	15%
SECOND INTERNAL EXAM			
V	**Energy from the oceans**. Ocean thermal electric conversion. Tidal energy conversion. Geothermal energy conversion. Hydro power-global and Indian scenario. Positive and negative attributes of hydropower. Electricity from hydropower. Small hydropower.	7	20%
VI	**Fuel cells.** Alkaline fuel cells. Phosphoric acid fuel cell. Molten carbonate fuel cell. Solid oxide fuel cell, Solid polymer electrolyte fuel cell. Magneto-hydrodynamic systems. Electric vehicles. Energy storage routes like thermal, chemical, mechanical, electrical storage. Batteries.	7	20%
END SEMESTER EXAMINATION			

QUESTION PAPER PATTERN:

Maximum Marks: 100 Exam Duration: 3 hours

The question paper consists of Part A, Part B and Part C.

Part A consists of three questions of 15 marks each uniformly covering Modules I and II. The student has to answer two questions (15×2=30 marks).

Part B consists of three questions of 15 marks each uniformly covering Modules III and IV. The student has to answer two questions (15×2=30 marks).

Part C consists of three questions of 20 marks each uniformly covering Modules V and VI. The student has to answer two questions (20×2=40 marks).

For each question there can be a maximum of 4 subparts.

Course Code	Course Name	L-T-P	Credits	Year of Introduction
BT364	Biorefinery Engineering	3-0-0	3	2016

Prerequisite : Nil

Course Objectives

- To provide an over view of the different types of renewable feed stocks and the basic knowledge needed to convert into fuels, power, heat, and value-added chemicals.

Syllabus

Fundamentals, environmental aspects, biorefinery processes and products, feedstocks and their characteristics, biochemical and thermochemical processing to obtain fuels and other chemicals, CO_2 capture using algae and its conversion to fuels and chemicals, Life Cycle Assessment.

Expected outcome

Upon successful completion of this course the student should be able to

i. Explain the need for biorefinery, principles and environmental aspects.
ii. Identify the most common sources of raw materials and their characteristics.
iii. Describe the salient features of different types of biorefineries.
iv. Explain biomass conversion processes.
v. Explain CO_2 capture using algae and its conversion to fuels and chemicals.

Reference Books

1. Jhuma Sadhukhan, KokSiew Ng, Elias Martinez Hernandez, *Biorefineries and Chemical Processes: Design, Integration and Sustainability Analysis*, John Wiley & Sons, 2013.
2. Paul R. Stuart, Mahmoud M. El-Halwagi, *Integrated Biorefineries: Design, Analysis, and Optimization*, CRC Press, 2013.
3. Chinnappan Baskar, Shikha Baskar, Ranjit S. Dhillon (Eds), *Biomass Conversion: The Interface of Biotechnology, Chemistry and Materials Science*, Springer, 2012.
4. Shang-Tian Yang, Hesham El-Ensashy, NutthaThongchul, *Bioprocessing Technologies in Biorefinery for Sustainable Production of Fuels, Chemicals and Polymers*. John Wiley & Sons, 2013.
5. Ashok Pandey, Rainer Höfer, Mohammad Taherzadeh, Madhavan Nampoothiri, Christian Larroche (Eds), *Industrial Biorefineries& White Biotechnology*, Elsevier, 2015.

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	**Fundamentals of Biorefinery**- Need for biorefinery, biorefinery principles, environmental aspects of biorefineries, Biorefinery products - biofuels such as ethanol, biodiesel, butanol, hydrogen, and biogas, biochemicals, and biopolymers, specialty chemicals and food ingredients, building block chemicals, Policy issues in biofuels, Indian biofuel programme,	7	15%
II	**Biorefinery feedstocks and their characteristics** - sugars, starch, oil, microalgae, energy crops - corn, soybeans, and sugarcane. Lignocellulosic biomass - wood, wood wastes and forestery residues, Lignocellulosic energy crops - *Miscanthus* spp. and various grasses, jatropha, bamboo, straw, cost and availability of biorefinery feedstocks, pre-treatments of biomass.	7	15%

FIRST INTERNAL EXAM			
III	**Biorefinery types** (based on platforms, products, feedstock, processes) and their features - C6 sugar platform biorefinery, Syngas platform biorefinery, C6 & C5 sugar and syngas platform biorefinery, SWOT (Strength, Weakness, Opportunities and Threat) analysis on a biorefinery, evaluating biorefinery performance, Life cycle analysis (LCA).	7	15%
IV	**Biochemical conversion**, enzymes for biochemical conversion and their properties - cellulases, xylanases, amylases, lignin-degrading enzymes, Fermentation - Production of platform chemicals, and their properties and uses - Lactic acid and Polylactic acid, Succinic acid, Acetic, Butyric and Itaconic acids.	7	15%
SECOND INTERNAL EXAM			
V	**Thermochemical Processing of Biomass**, General features of thermochemical conversion processes, Combustion, Pyrolysis, Gasification, bio-oil, bio-oil refining, bio-oil upgrading, Thermochemical Processing of Bio-Oil into Fuels, Methanol Production, Bio-Oil Co-Processing in Crude Oil Refinery, chemicals from thermochemical processing	8	20%
VI	**Algae Biorefineries**- basic principles, CO_2 capture, biological kinetics and yields, algae cultivation, open pond cultivation, photobioreactors, algae harvesting and oil extraction, algae biodiesel production, heterogeneous catalysts for transesterification, algae biorefinery integration, Life Cycle Assessment of algae biorefineries and environmental implications, Economic analysis.	7	20%
END SEMESTER EXAMINATION			

QUESTION PAPER PATTERN:

Maximum Marks: 100 Exam Duration: 3 hours

The question paper consists of Part A, Part B and Part C.

Part A consists of three questions of 15 marks each uniformly covering Modules I and II. The student has to answer two questions (15×2=30 marks).

Part B consists of three questions of 15 marks each uniformly covering Modules III and IV. The student has to answer two questions (15×2=30 marks).

Part C consists of three questions of 20 marks each uniformly covering Modules V and VI. The student has to answer two questions (20×2=40 marks).

For each question there can be a maximum of 4 subparts.

Course Code	Course Name	L-T-P	Credits	Year of Introduction
BT364	Biorefinery Engineering	3-0-0	3	2016

Prerequisite : Nil

Course Objectives

- To provide an over view of the different types of renewable feed stocks and the basic knowledge needed to convert into fuels, power, heat, and value-added chemicals.

Syllabus

Fundamentals, environmental aspects, biorefinery processes and products, feedstocks and their characteristics, biochemical and thermochemical processing to obtain fuels and other chemicals, CO_2 capture using algae and its conversion to fuels and chemicals, Life Cycle Assessment.

Expected outcome

Upon successful completion of this course the student should be able to

i. Explain the need for biorefinery, principles and environmental aspects.
ii. Identify the most common sources of raw materials and their characteristics.
iii. Describe the salient features of different types of biorefineries.
iv. Explain biomass conversion processes.
v. Explain CO_2 capture using algae and its conversion to fuels and chemicals.

Reference Books

1. Jhuma Sadhukhan, KokSiew Ng, Elias Martinez Hernandez, *Biorefineries and Chemical Processes: Design, Integration and Sustainability Analysis*, John Wiley & Sons, 2013.
2. Paul R. Stuart, Mahmoud M. El-Halwagi, *Integrated Biorefineries: Design, Analysis, and Optimization*, CRC Press, 2013.
3. Chinnappan Baskar, Shikha Baskar, Ranjit S. Dhillon (Eds), *Biomass Conversion: The Interface of Biotechnology, Chemistry and Materials Science*, Springer, 2012.
4. Shang-Tian Yang, Hesham El-Ensashy, NutthaThongchul, *Bioprocessing Technologies in Biorefinery for Sustainable Production of Fuels, Chemicals and Polymers*. John Wiley & Sons, 2013.
5. Ashok Pandey, Rainer Höfer, Mohammad Taherzadeh, Madhavan Nampoothiri, Christian Larroche (Eds), *Industrial Biorefineries& White Biotechnology*, Elsevier, 2015.

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	**Fundamentals of Biorefinery**- Need for biorefinery, biorefinery principles, environmental aspects of biorefineries, Biorefinery products - biofuels such as ethanol, biodiesel, butanol, hydrogen, and biogas, biochemicals, and biopolymers, specialty chemicals and food ingredients, building block chemicals, Policy issues in biofuels, Indian biofuel programme,	7	15%
II	**Biorefinery feedstocks and their characteristics** - sugars, starch, oil, microalgae, energy crops - corn, soybeans, and sugarcane. Lignocellulosic biomass - wood, wood wastes and forestery residues, Lignocellulosic energy crops - *Miscanthus* spp. and various grasses, jatropha, bamboo, straw, cost and availability of biorefinery feedstocks, pre-treatments of biomass.	7	15%

FIRST INTERNAL EXAM			
III	**Biorefinery types** (based on platforms, products, feedstock, processes) and their features - C6 sugar platform biorefinery, Syngas platform biorefinery, C6 & C5 sugar and syngas platform biorefinery, SWOT (Strength, Weakness, Opportunities and Threat) analysis on a biorefinery, evaluating biorefinery performance, Life cycle analysis (LCA).	7	15%
IV	**Biochemical conversion**, enzymes for biochemical conversion and their properties - cellulases, xylanases, amylases, lignin-degrading enzymes, Fermentation - Production of platform chemicals, and their properties and uses - Lactic acid and Polylactic acid, Succinic acid, Acetic, Butyric and Itaconic acids.	7	15%
SECOND INTERNAL EXAM			
V	**Thermochemical Processing of Biomass**, General features of thermochemical conversion processes, Combustion, Pyrolysis, Gasification, bio-oil, bio-oil refining, bio-oil upgrading, Thermochemical Processing of Bio-Oil into Fuels, Methanol Production, Bio-Oil Co-Processing in Crude Oil Refinery, chemicals from thermochemical processing	8	20%
VI	**Algae Biorefineries**- basic principles, CO_2 capture, biological kinetics and yields, algae cultivation, open pond cultivation, photobioreactors, algae harvesting and oil extraction, algae biodiesel production, heterogeneous catalysts for transesterification, algae biorefinery integration, Life Cycle Assessment of algae biorefineries and environmental implications, Economic analysis.	7	20%
END SEMESTER EXAMINATION			

QUESTION PAPER PATTERN:

Maximum Marks: 100 Exam Duration: 3 hours

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Part B consists of three questions of 15 marks each uniformly covering Modules III and IV. The student has to answer two questions (15×2=30 marks).

Part C consists of three questions of 20 marks each uniformly covering Modules V and VI. The student has to answer two questions (20×2=40 marks).

For each question there can be a maximum of 4 subparts.

Course Code	Course Name	L-T-P	Credits	Year of Introduction
BT366	**Bioremediation Technology**	**3-0-0**	**3**	**2016**

Course Objectives

- To introduce the microbiological and engineering fundamentals of bioremediation for treating municipal, agricultural and industrial contaminants.

Syllabus

Introduction to bioremediation; bioremediation and the societal and legal background, mechanisms, metabolic process, global applications, construction of biomembrane reactors, degradation mechanisms.

Expected outcome

Upon successful completion of the course the student will be able to

i. Explain different types of bioremediation processes.
ii. Explain the metabolic processes involved in bioremediation.
iii. Describe the bioremediation of soil, air, and water.
iv. Explain the principle of phytoremediation.
v. Explain the problems associated with the disposal of hazardous wastes.

Reference Books

1. Bruce E Rittmann, Perry L McCarty, *Environmental Biotechnology: Principles and Applications*, McGraw-Hill, 2001.
2. Agarwal K, *Environmental Biotechnology*, APH Publishing, 2000.
3. Martin Alexander, *Biodegradation &Bioremediation*, Academic Press, 1999.
4. Singh A, Ward OP, *Biodegradation and bioremediation*, Springer-Verlag, 2004.
5. Baker KH, Herson DS, *Bioremediatio*n, McGraw-Hill, Inc., New York, 1994.

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	**Introduction to Bioremediation**: Types of Bioremediation - Bioremediation and the societal and legal background - Factors affecting Bioremediation – Bioremediation Mechanisms - Limitations of Bioremediations - In-situ & Ex-situ bioremediation techniques.	7	15%
II	**Microbes for Bioremediation**: Microbes involved in Bioremediation - Essential characteristics of microbes for Bioremediation - Microbial adaptation for adverse conditions - Metabolic process involved in bioremediation. Biodegradation of polyhalogenated compounds by genetically engineered bacteria.	7	15%
	FIRST INTERNAL EXAM		
III	Advantages and disadvantages of specific bioremediation technologies - Land farming - Prepared beds - Biopiles, composting – Bioventing - Pump and Treat method - Constructed wetlands - Use of bioreactors for bioremediation - Global application of Bioremediation	7	15%

IV	Bioremediation – Soil, Air, water & metals - Effects of Co-substrates on microorganisms – Rhizoremediation - Molecular techniques in bioremediation - Methods for monitoring and assessment of bioremediation process- Microbial transformation - Accumulation and concentration of metals	7	15%
SECOND INTERNAL EXAM			
V	**Emerging Techniques:** Phytoremediation – sequestering carbon Dioxide – Biomonitoring - Application of Microbial Enzymes - Construction of Biomembrane Reactors for Bioremediation -Microbial interactions with heavy metals - resistance &tolerance -Biosorption of heavy metals by microbial biomass and secondary metabolites – Biosurfactants.	8	20%
VI	Problems associated with disposal of xenobiotic compounds - Biodegradation of xenobiotics - Hazardous wastes – Persistent compounds - Degradation mechanisms - naphthalene, benzene, phenol, PCB's, propanil (Herbicide), urea - Biodegradation of petrochemical effluents - Case Studies.	7	20%
END SEMESTER EXAMINATION			

QUESTION PAPER PATTERN:

Maximum Marks: 100 Exam Duration: 3 hours

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Part C consists of three questions of 20 marks each uniformly covering Modules V and VI. The student has to answer two questions (20×2=40 marks).

For each question there can be a maximum of 4 subparts.

Course No.	Course Name	L-T-P	Credits	Year of Introduction
BT368	Genetic Engineering	3-0-0	3	2016

Prerequisite: Nil

Course Objectives

- To provide an advanced introduction to the field of genetic engineering, which constitutes the most popular realm of Biotechnological application.
- To describe the gene cloning tools and techniques and the heterologous expression of cloned genes in different hosts, production of recombinant proteins and PCR techniques.

Syllabus

Tools in Genetic Engineering , Ligation Strategies, Labeling of DNA, Hybridization techniques, DNA-Protein Interactions, Cloning Vectors, Expression vectors, Protein purification, Cloning Methodologies, PCR and its Applications, Mutation detection, Sequencing methods, Gene silencing techniques, Methods of gene transfer, Gene knockouts, Gene Therapy,Recombinant proteins, Transgenics

Expected outcome

Upon successful completion of this course, the students will

i. Get familiar with the basic tools used in genetic engineering.
ii. Understand different types of interactions and hybridization techniques.
iii. Distinguish and identify specific vectors for different cloning purposes.
iv. Get familiar with the basic principles, techniques and applications of gene cloning.

Reference Books

1. Primrose S B, Twyman R M, Old R W, *Principles of Gene Manipulation*, 6/e, Blackwell Science Limited, 2001.
2. Sambrook J, Russel D W, *Molecular Cloning: A Laboratory Manual*, Cold Spring Harbour Laboratory Press, 2012.
3. Desmond ST, Nicholl, *Introduction to Genetic Engineering*, Cambridge University Press, 2004.
4. Joshi P., *Genetic Engineering and its applications*, Agrobios, India, 2004.
5. Smita Rastogi, Neelam Pathak, *Genetic Engineering*, Oxford University Press, Edition I, 2009.

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	**Tools in Genetic Engineering:** Restriction Enzymes, DNA ligase, Klenow enzyme, T4 DNA polymerase, Polynucleotide kinase, Alkaline phosphatase, Reverse transcriptase. **Ligation Strategies:** Cohesive and blunt end ligation, Linkers, Adaptors, Homopolymeric tailing. **Labeling of DNA:** Nick translation, Random priming, End labelling, Radioactive and nonradioactive probes	5	15%

II	**Hybridization techniques:** Northern, Southern and Colony hybridization, Fluorescence *in situ* hybridization, Homologous Recombination, Western Blotting. **DNA-Protein Interactions**: Chromatin Immunoprecipitation, Electromobility shift assay, DNAaseI footprinting, Methyl interference assay.	5	15%
FIRST INTERNAL EXAM			
III	**Cloning Vectors:** Plasmids, Bacteriophages, M13 mp vectors, PUC19 and Bluescript vectors, Phagemids, Lambda vectors: Insertion and Replacement vectors, pEMBL,Cosmids, Artificial chromosome vectors (YACs, BACs), Viral vectors. **Expression vectors**: pET based vectors **Protein purification**: His-tag, GST-tag. **Cloning Methodologies:** Insertion of Foreign DNA into Host Cells, Transformation, Construction of libraries, Isolation of mRNA and total RNA,cDNA and genomic libraries, Expression cloning, Protein-protein interactive cloning and Yeast two hybrid system, Phage display.	10	15%
IV	**PCR and Its Applications:** Primer design, Fidelity of thermostable enzymes, DNA polymerases, Types of PCR- real time PCR, hot start PCR, colony PCR, nested PCR, multiplex PCR. Cloning of PCR products: T-vectors, Proof reading enzymes, Applications of PCR, gene amplification and diagnostics. **Mutation detection:** SSCP, DGGE, RFLP, Oligo Ligation Assay (OLA), MCC (Mismatch Chemical Cleavage, ASA (Allele-Specific Amplification), PTT (Protein Truncation Test).	8	15%
SECOND INTERNAL EXAM			
V	**Sequencing methods:** Enzymatic DNA sequencing, Chemical sequencing of DNA, Automated DNA sequencing. **Gene silencing techniques:** Introduction to siRNA, siRNA technology, Micro RNA, Construction of siRNA vectors, Principle and application of gene silencing. **Methods of gene transfer:** Gene transfer in Animals, Agrobacterium mediated gene transfer and biolistic. **Gene knockouts:** Creation of knockout mice, Disease model	9	20%
VI	**Gene Therapy:** Somatic and germ-line therapy- *in vivo* and *ex-vivo*, Gene replacement, Gene targeting **Production of recombinant proteins**: Production of insulin, growth hormones and monoclonal antibodies. **Transgenics:** Biopharming. Transgenic animals - transgenic mouse, transgenic fish. Transgenic plants-Genetically modified crops, Insect resistant and herbicide resistant plants	7	20%
END SEMESTER EXAMINATION			

QUESTION PAPER PATTERN:

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