B.TECH THIRD YEAR SYLLABUS CHEMICAL ENGINEERING

V SEMESTER

Sl. No.	Course type	Subject code	Course Name	L	T	P	Credits
1	**DC**	CH 3101	Mass Transfer II	3	1	0	4
2	**DC**	CH 3102	Chemical Reaction Engineering II	3	0	0	3
3	**DC**	CH 3103	Instrumentation and Process Control	3	1	0	4
4	**DC**	CH 3106	Chemical Process Technology & Safety	3	0	0	3
5	**DE**		Department Elective-I	3	0	0	3
6	**DP**	CH3104	Chemical Reaction Engineering lab	0	0	3	2
7	**DP**	CH3105	Instrumentation and Process Control lab	0	0	3	2
			Total	**15**	**2**	**3**	**21**

VI SEMESTER

Sl. No.	Course type	Subject code	Course Name	L	T	P	Credits
1	**DC**	CH3201	Transport Phenomena	3	1	0	4
3	**DC**	CH3202	Data Analytics	3	0	0	3
4	**DC**	CH 3203	Computer Aided Process Engineering	2	0	3	4
5	**DE**		Department Elective-II	3	0	0	3
6	**OE**		Elective- I	3	0	0	3
7	**DP**	CH 3205	Mass Transfer Lab	0	0	3	2
8	**PR I**	CH3206	Project-I	0	0	3	2
			Total	**14**	**1**	**9**	**21**

List of Department Electives	
Department Electives	1. Bio Chemical Engineering 2. Process Optimization 3. Process Integration System and Design

Note: Department Electives will be offered based on the availability of resource person.

V SEMESTER

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	CH 3101	Mass Transfer II	3	1	0	4

Course Objective

This course enables the students:

1. To acquire basic knowledge of mass transfer operation and its application.
2. To learn fundamental knowledge of mass transfer involved in various unit operations.
3. To design mass transfer processes and equipment.

Learning Outcomes

After the completion of this course, students will be to:

1. Explain the gas-solid contacting process and solve related problems including Drying.
2. Understand basics of adsorption, chromatography and ion-exchange.
3. Explain membrane filtration.
4. Develop a process design for liquid-liquid extraction and leaching.

Unit No.	Topics to be Covered	Learning Outcome

1.	Drying: Theory and mechanism of drying, Batch and continuous drying; Drying rate curves, Estimation of drying times, Cross-circulation and through-circulation drying, Transfer unit concept in drier, Design calculations with special reference to rotary and spray driers.	Concept, design and problem solving on Drying.
2.	Liquid-Liquid Extraction: Ternary liquid equilibria, Partial miscibility, Solvent selection, Crosscurrent and counter-current multistage extraction, Extraction with reflux, Extraction equipment, Performance evaluation of extractors.	Concept, design and problem solving on LLE.
3.	Leaching: Solid-liquid equilibria, Single and multistage, Cross-current and countercurrent leaching, Steady state and unsteady state operations, Operation and performance evaluation of leaching equipment's.	Concept, design and problem solving on Leaching.
4.	Adsorption and Ion Exchange: Adsorption equilibria - Various isotherms, Breakthrough curves, Ion exchange equilibria, Contact filtration, Design of adsorbers and ion exchangers, Chromatography.	Concept, design and problem solving on Adsorption.
5.	Membrane Separations: Reverse osmosis, Dialysis, Microfiltration, Ultrafiltration; Pervaporation, Separation of gases and liquids.	Concept, design and problem solving on Membrane Separation.
6.	Crystallization: Theory of solubility Crystallization, phase diagram (temp/solubility relationship), crystal geometry; crystal nucleation and growth; equilibria and yields.	Concept, design and problem solving on Crystallisation.

Text Book :

1. R. E. Treybal, Mass Transfer Operations, McGraw Hill Education 2017.
2. W. L. McCabe, J. C. Smith and P. Harriott, Unit Operations of Chemical Engineering, McGraw Hill Education 2017.
3. E. I. Cussler, Diffusion: Mass Transfer in Fluid Systems, Cambridge University Press 2009.

Reference:

1. J.F. Richardson, J. H. Harker, and J. R. Backhurst, Coulson & Richradson's Chemical Engineering, Volume 2 Butterworth-Heinemann 2002.

2. B.K. Dutta, Principles of Mass Transfer and Separation Processes, Prentice Hall India Learning Private Limited, 2006.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	CH3102	Chemical Reaction Engineering-II	3	0	0	3

Course Objective

1. To provide the student with principles and kinetic tools useful in analyzing the rates of chemical reactions for both heterogeneous non-catalytic and catalytic reactions.

Learning Outcomes

After the completion of this course, students will be to:

1. Understand the effect of velocity, particle size and fluid properties on rate of reactions controlled by mass transfer.
2. Understand the design aspects of multiphase reactors.
3. Design industrial reactors involving chemical reactions with mass transfer.
4. Determine internal and overall effectiveness factors.

Unit No.	Topics to be Covered	Learning Outcome
1.	Multiphase reactions: Introduction to heterogeneous reactions and effects of mass and heat transfer. Gas-Liquid, Liquid-Liquid, Gas-Solid, Solid-Liquid-Gas reactions.	Basics of heterogeneous reactions and rate equations for Gas-Liquids, Liquid-Liquid, Gas-Solid, Solid-Liquid-Gas reactions.
2.	Catalyst preparation and characterization. Mechanism of catalytic reactions, Rate equations for solid catalyzed fluid phase reactions, External mass and heat transfer in catalyst particles, Effectiveness factor, Deactivation of catalyst.	Reactor design for non-catalytic reactions i.e, fluid-fluid and fluid-solid reactions.
3.	Models of Industrial Reactors (Packed bed, slurry, trickle bed, fluidized bed): Pressure Drop considerations, Heat management.	

Text Books:

1. Levenspiel O, Chemical Reaction Engineering, 3rd Edition, Wiley India (1999).
2. Fogler S H, Elements of Chemical Reaction Engineering, 4th Edition, Prentice Hall India (2015).
3. J. M. Smith,Chemical Engineering Kinetics, McGraw Hill 1981.
4. K. R. Westerterp, W. P. M. Van Swaaij and A. A. C. M. Beenackers, Chemical Reactor Design and Operation by Wiley Blackwell 1987.

Reference Books:

1. Schmidt L D, The Engineering of Chemical Reactions, 2nd Edition, Oxford University Press (2005).
2. Froment G F and Bischoff K B, Chemical Reactor Analysis and Design, 2nd Edition, John Wiley & Sons (1990).
3. Doraiswamy L K and Uner D, Chemical Reaction Engineering: Beyond the Fundamentals, 1st Edition, CRC Press (2013).

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	CH3103	Instrumentation and Process Control	3	1	0	4

Course Objective

This course enables the students:

1. To acquire basic knowledge of measurement devices for temperature, pressure, vacuum, fluid flow rate, level and control valves.
2. To understand the control relevant model development.
3. To design feedback control strategies for different processes..

Learning Outcomes

1. Use suitable instruments for measurement of temperature, pressure, vacuum, fluid flow rate, level.
2. Develop control relevant mathematical models.
3. Analyze stability and frequency response.
4. Design simple and advanced regulatory controllers for different processes.
5. Analyze multi input multi output control loops.

Unit No.	Topics to be Covered	Learning Outcome
1.	**Instrumentation:** Static and dynamic characteristic of instruments. Measurement of temperature, pressure, vacuum, fluid flow rate, level and control valves.	Use suitable instruments for measurement of temperature, pressure, vacuum, fluid flow rate, level.
2.	**Process Control:** Modelling considerations for control purposes. • State Space and Transfer function models. • Dynamic behaviour of first and higher order systems. • Concept and dynamic behaviour of feedback control. Frequency response analysis. Stability analysis of feedback systems. Design of feedback controllers. • Feedforward, Ratio, Adaptive and inferential control, dead-time and inverse response compensator.	Develop control relevant mathematical models. Analyse stability, frequency response, Design of simple controllers for different processes.

	• Control systems with multiple loops.	

Text/Reference Books:

1. G. Stephanopoulos, Chemical process control: An introduction to theory and practice, Prentice Hall India 2008.
2. D. E. Seborg, T. F. Edgar, D. A. Mellichamp, and F.J. Dyle III, Process dynamics and control, Wiley 2010.
3. D. Patranabis, Principles of industrial instrumentation, Tata McGraw Hill 2008.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	**CH3104**	Chemical Process Technology & Safety	3	0	0	3

Course Objective

1. To offer students a broad background and overview of chemical industries.
2. This course provides a chance to explore chemical industries on the basics of unit process and unit operation concepts.
3. Learn safety norms to follow in industry.

Learning Outcomes

At the end of the course, the student will be able to:
1. To clearly distinguish function role and importance of various processes and operation in the plant
2. To get clear technical knowledge in selection of operating conditions such as temperature, pressure and compositions
3. Draw the chemical industry flow sheet by using unit operation and unit processes
4. Understand the process safety rules to follow in chemical industry

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1.	Scope of Chemical process technology in process industries, Unit process: Various reactions used in chemical industry, Reactors and their working principles. Unit operations: Mechanical operations, fluid mechanics, mass and heat transfer equipment	3	Learns the fundamentals of chemical industries and need of CPT course

2.	Inorganic chemical process industries and Sulphur production of sulphur: Frasch and Claus Process, Production of Sulphuric acid: Contact Process	3	Learns the sulphur and sulphuric acid production process
3.	Introduction of nitrogen industries, Manufacturing process of ammonia by Haber synthesis method, Manufacturing process of nitric acid, Manufacturing process of Urea, ammonia nitrate and calcium ammonia nitrate	4	Learns nitrogen and ammonia production process
4.	Introduction of phosphorous industries and production of phosphorous, Manufacturing process of phosphoric acid and ammonia phosphate, Production of calcium phosphates: Single super phosphate and Triple super phosphate	3	Learns Phosphorous, Phosphoric acid and super phosphates production
5	Chlor-Alkali industries: Manufacturing process of sodium carbonate: Solvay process and Leblanc process, Manufacturing of chlorine and caustic soda	3	Learns chlor-alkali industry and Solvay process
6	Cement and Lime: Different cement properties and production of cement, Natural Product Industry: Manufacturing process of Soaps and Detergents, Pulp and paper production: Kraft sulfate process	4	Learns cement, soap and paper manufacturing process
7	Organic chemical industries: Overview of refining process, different components and properties of crude oil, Refinery operations: Distillation, Alkylation, Reforming, Cracking, Hydro treating and Isomerization etc., Manufacturing process of organic chemicals from refinery by products.	11	Learns the crude oil refining and various refinery operation
8	Safety in chemical industry, Forms of hazards, control and prevention of hazards, Risk analysis: HAZOP Safety audit, Safety and Environmental Management Systems (SEMS)	6	Learns safety in industry and risk analysis
9	Characteristics of chemical with special reference to safe storage & handling. Layout of storage, modes of transport, associated hazards control and prevention. Analysis of documented accidents, Asphyxiation, respiratory and skin effect of petroleum hydrocarbons, sour gases	3	Learns the safe handling and transport of chemicals

	Total Classes	**40**	

Text Books:

1. Shreve's Chemical Process Industries by G.T. Austin, Fifth edition, Tata McGraw Hill (2012).

2. Dryden's Outlines of Chemical Technology by M.G. Rao, Third edition, East West Press (2018).

3. Crowl, D.A., Louvar, J. F., "Chemical Process Safety – Fundamentals with Applications". Prentice-Hall, Pearson, 2011.

References:

1. Moulijn J.K; Makkee M. and van Diepen A;"Chemical Process Technology", Second edition, Wiley (2013). 2. Riegel's Hand Book of Industrial Chemistry by James A Kent, Ninth edition, CBS publishers & distributors (1997).

2. CCPS," Guidelines for Engineering Design for Process Safety", AIChE.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	CH 30007	Instrumentation and Process Control Lab	0	0	2	2
Course Objective						
1. Course aims to help the students to gain in-depth understanding of the concepts that were taught in the theory course of instrumentation and process control through hands-on experiments on responses of the systems, Calibration and characterization of instruments.						
Learning Outcomes						
1. Understand how to setup experiments to study the dynamic response and evaluate the time constants of different first order and second order systems. 2. Understand how to setup experiments to calibrate and characterize instruments.						

Unit No.	Topics to be Covered	Learning Outcome

1.	Calibration experiments on thermocouple, resistance thermometer, thermistor. Study and calibration of flapper nozzle assembly, pneumatic and electronic DP transmitter, I/P and P/I converters.	Understand and experience the response of first order and second order systems.
2.	Studies on control valve characteristics. Experiments on Dynamic behavior for interacting and non-interacting tank level system, and temperature control (integrated system). Control performance studies on pressure process, tank level system, heat exchanger.	Understand the different types of valve characteristics. Learn how to calibrate a thermocouple and understand it response. Learn about wastewater management techniques in various industries.

Text Book:

1. G. Stephanopoulos, Chemical process control: An introduction to theory and practice, Prentice Hall India 2008.
2. D. Patranabis, Principles of industrial instrumentation, Tata McGraw Hill 2008.

Reference:

1. D. E. Seborg, T. F. Edgar, D. A. Mellichamp, & F.J. Dyle III, Process dynamics and control, Wiley 2010.

Course Type	**Course Code**	**Name of Course**	**L**	**T**	**P**	**Credit**
DP		Chemical Reaction Engineering Lab	0	0	3	2

Course Objective
1. Course aims to equip students with hands on experience in different aspects of chemical reaction engineering.
Learning Outcomes

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

1. Carry out Experiments in homogenous and heterogeneous phases in Batch, Plug flow, Mixed flow reactors.
2. Observe, analyze and interpret the kinetic data for different reactions.
3. Estimate the mass transfer coefficient in agitated vessels and estimate the RTD in packed/un packed tubular reactor.

Unit No.	Topics to be Covered	Learning Outcome
1.	Study of liquid phase homogenous reaction in Batch /Plug flow/Three Staged Mixed reactors.	Hands on experience on Reaction Engineering equipment and various reaction condition optimization.
2.	Development of rate equations for catalytic gas solid reaction.	
3.	Evaluation of mass transfer coefficient in an agitated contactor, Catalytic reaction studies in Berty Reactor.	
4.	RTD studies for water flowing in a tubular reactor with packing/without packing.	

Text Books:

1. Levenspiel O, Chemical Reaction Engineering, 3rd Edition, Wiley India (1999).
2. Fogler S H, Elements of Chemical Reaction Engineering, 4th Edition, Prentice Hall India (2015).

VI SEMESTER

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	CH 3201	Transport Phenomena	4	0	0	4
Course Objective						

1. To provide students the basics of vector and tensor operations and their applications.
2. To enable students to understand concepts in momentum transfer, shell balance, governing equations and relevant boundary conditions.
3. To enable students to solve the flow problems using different physical systems and different boundary conditions.
4. To provide students with the derivation of the Navier-Stokes equation, energy balance equations for different systems will be explained.
5. To provide students with knowledge of derivations and solution of equations governing coupled heat, mass and momentum transfer problems.

Learning Outcomes

1. Explain the various types of transport processes relevant in chemical operations.
2. Demonstrate mastery over Vectors and Tensor calculus and its use in solving complex transport problems.
3. Apply concept of Shell Balances for Momentum, Energy and Mass Transport and use the same to solve various transport problems.
4. Apply fundamentals of transport phenomena to solve actual industrial problems involving all these processes simultaneously and understand the similarities among them.

Unit No.	Topics to be Covered	Learning Outcome
1.	Brief revision on 'Transport by molecular motion: Newton's Law of viscosity, Fourier's law of heat conduction, Fick's law of diffusion. Transport in laminar flow or in solids in one dimension.	Demonstrate mastery over Vectors and Tensor calculus and its use in solving complex transport problems.
2.	Development of continuity (conservation) equations, velocity, temperature and concentration profiles, momentum, energy and mass fluxes. Equations of change for isothermal, non-isothermal and multicomponent systems.	Apply concept of Shell Balances for Momentum and use the same to solve various momentum transport problems.
3.	Navier-Stokes equation, equation of energy, equations of motion for free and forced convection (heat/mass). Unsteady state viscous flow, heat conduction and mass diffusion. Momentum, energy and mass transport in boundary layer with relevant analogies.	Apply the concept of Shell Balances for energy and use the same to solve various simultaneous momentum and energy transport problems.

4.	Transport in turbulent flow: time smoothened equations of change. Interphase momentum, heat and mass transfer.	Understand diffusive and convective mass flux, derive species balance equations, and solve species transport problems in multicomponent problems.

Text Book:

1. Bird,R.B., Stewart, W.E. and Lightfoot, E.W. Transport Phenomena, Wiley, 1994.
2. Welty J, Wicks C.E., Rorrer G.L., Wilson R.E., Fundamentals of Momentum, Heat and Mass Transfer, Wiley, 2008.

Reference:

1. Brodkey R.S., Hershey H.C., Transport Phenomena-A unified approach, McGraw Hill, 1988.

2. Slattery J.C., Advanced Transport Phenomena, Cambridge University Press, 1999.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	CH3203	Computer Aided Process Engineering	2	0	3	4

Course Objective

To introduce computational techniques to UG students in order to solve chemical engineering problems by applications of process simulation software's such as MATLAB and Aspen.

Learning Outcomes

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

1. Familiar with the basics of MATLAB and ASPEN
2. Solve the chemical engineering models by computational technique.
3. Design a unit process and unit operation equipment.

Unit No.	Topics to be Covered	Learning Outcome
1.	Review of numerical methods using Chemical Engineering applications - solution of linear and nonlinear algebraic equations, solution of coupled ordinary differential equations using MATLAB.	Basics of numerical techniques and their application in chemical engineering problems.
2.	Solution of ordinary differential equations, regression and optimization problems using MATLAB. Importance of VLE/ LLE calculations for process simulation.	Learn how to solve chemical engineering ordinary differential equation, regression and optimization problems
3.	Process modeling and simulation, Information Flow diagram, modeling of different process equipment - heat exchangers, boilers, evaporator, L-L extraction, furnaces, flash drum, distillation, absorption, other staged / differential contacting processes, reactors etc. Sensitivity and design specification problems in ASPEN	Learn how to build a aspen simulation and solve the flow sheet and independent blocks

Text Books:

1. N. Kaisare, Computational techniques for process simulation and analysis using Matlab. CRC Press (2017).
2. Introduction to Chemical Engineering Computing, Second Edition by Bruce A. Finlayson.Wiley (2014).
3. Numerical Methods for Engineers 7th Edition, Steven C. Chapra and Raymond P. Canale.McGraw hill publishers (2016).

References:

1. S.K. Gupta, Numerical Methods for Engineers. New Age International Publishers (2015).
2. R.G.E. Franks, Modeling and simulation in chemical engineering, Wiley Blackwell (1972).
3. Kamal l. M. Al-Malah Aspen Plus: Chemical Engineering Applications, Wiley (2016).

Text Books:

1. Smith, R., Chemical Process Design and Integration, John Wiley & Sons (2005).
2. W. D. Seider, J. D. Seader, D. R. Levin and S. Widagdo, Product and Process Design Principles: Synthesis, Analysis and Design, 3rd Ed.; Wiley, New York, 2009.
3. Kamal I.M. Al-Malah, Aspen Plus: Chemical Engineering Applications Wiley (2016).
4. Linnhoff, D.W., User Guide on Process Integration for the Efficient Use of Energy, Institution of Chemical Engineers (1994).

References:

1. T. F. Edgar, D. M. Himmelblau and L. S. Lasdon, Optimization of Chemical Processes, 2nd Ed., McGraw Hill, New York, 2001.
2. G. Towler and R. K. Sinnot, Chemical Engineering Design, Elsevier, Oxford, UK.
3. S. Thakore and B. Bhatt, Introduction to Process Engineering Design, Tata McGraw Hill, New Delhi, India, 2008.
4. B. V. Babu, Process Plant Simulation, Oxford University Press, New Delhi, 2004.
5. Shenoy, V. U., Heat Exchanger network synthesis, Gulf Publishing (1995).
6. Kumar, A., Chemical Process Synthesis and Engineering Design, Tata McGraw Hill (1977).
7. A.K. Jana, Process Simulation and Control using Aspen. Prentice Hall India (2012).

Course Type	Course Code	Name of Course	L	T	P	Credit

DC	CH3202	Data Analytics	3	0	0	3

Course Objective

1. To introduce students to basic applications, concepts, and techniques of data science concepts.
2. To understand various key paradigms for machine learning approaches.
3. To understand and differentiate among various machine learning techniques.

Learning Outcomes

Student will be able to:

1. Understand the need for data analysis.
2. Learn statistics, linear algebra and optimization from a data science perspective.
3. Design and implement machine learning solutions to classification, regression, and clustering problems; and be able to evaluate and interpret the results of various machine learning algorithms.
4. Describe why machine learning techniques are able to cross-cut several disciplines.

Unit No.	Topics to be Covered	Learning Outcome
1.	**Introduction:** Introduction to Data Analytics, Machine Learning and Artificial Intelligence. Data Quality and Pre-processing.	Student will understand the need forthis course and also learn the data pre-processing techniques.
2.	**Descriptive Statistics:** Graphical approach - Frequency tables, relative frequency tables, grouped data, pie chart, bar chart, histograms, ogives, stem and leaf plots, box plots, dot diagram, scatter plots, Pareto diagram. Measure of Central Tendency and Dispersion **-** Arithmetic mean, median and mode, variance, standard deviation, quartiles, range, mean absolute deviation, coefficient of variation, Z scores, normal distribution, confidence interval estimation.	Student will learn to calculate and interpret the various measures of central tendency, dispersion skewness. Analyse and compare different sets of data. Making an inference about a population from asample.
3.	**Probability Distribution and Inferential Statistics:** Random variables, probability distributions, hypothesis testing, single sample test, two sample test, Type I error, Type II error.	Students will understand the concepts of inferential statistics which are required for data science.

4.	**Optimization for Data science and examples.**	Different optimization techniques will be learned which are required for machine learning algorithms.
5.	**Supervised Learning:** Linear regression, ridge regression, Lasso regression, logistic regression, multiple linear regression, goodness of fit, bias–variance trade off, k-nearest neighbors' algorithm, linear discriminant analysis, classification and regression trees and pruning, support vector machines, random forest, Naive Bayes, Introduction to deep learning.	Design and implement supervised learning solutions to classification, regression; and be able to evaluate and interpretthe results of various machine learning algorithms.
6.	**Unsupervised Learning:** Dimensionality reduction, Cluster analysis – K Means, Hierarchical, Density based methods.	Design and implement unsupervisedlearning solutions to dimensionality reduction and clustering problems
7.	**Reinforcement Learning.** **Applications to Different Processes. Use of Python.**	Understand the importance of reinforcement learning and use of Python for machine learning applications

Text Books:

1. Data Analytics: Models and Algorithms for Intelligent Data Analysis, Thomas A. Runkler, Springer, 2012.

2. A General Introduction to Data Analytics, João Mendes Moreira , André C. P. L. F. de Carvalho, Tomáš Horváth, Wiley, 2018.

3. Introduction to Machine Learning, Ethem Alpaydın,4 th Edition, MIT Press, 2020.

References:

1. Applied Statistics and Probability for Engineers, Douglas C. Montgomery, George C. Runger, 7th Edition, Wiley, 2019.

2. Introduction to Data Mining, Pang-Ning Tan, Michael Steinbach, Anuj Karpatne, Vipin Kumar, 2nd Edition, Pearson, 2019.

3. Data Mining: Concepts and Techniques, Jiawei Han, Micheline Kamber, Jian Pei, 3 rd Edition, Elsevier, 2012.

4. Keith R. Holdaway, Harness Oil and Gas Big Data with Analytics: Optimize exploration and Production with Data Driven Models, Wiley, 2014.

Books on Python:

1. Introduction to Data Science: A Python Approach to Concepts, Techniques and Applications, Laura Igual, Santi segui, Springer, 2017.

2. Python for Data Analysis, Wes McKinney, O' Relley, 2013.

Online Resources:

1. https://nptel.ac.in/courses/106/107/106107220/

2. https://nptel.ac.in/courses/110/106/110106072/

Course Type	Course Code	Name of Course	L	T	P	Credit
DP	CH 30013	Mass Transfer Laboratory	0	0	3	2
Course Objective						
To provide hands-on experience and practical knowledge of various mass transfer operations through lab scale experiments.						
Learning Outcomes						
At the end of the course, the student will be able to 1. Determine diffusion coefficient and interpret adsorption data. 2. Understand and operate different types of lab scale distillation apparatus. 3. Compute drying calculations and estimate drying time.						

Unit No.	Topics to be Covered	Learning Outcome
1.	Determination of Diffusion Coefficient of Air-Acetone by Stefan's method.	Hands on experience on mass transfer equipment and property estimation.
2.	T-X-Y equilibrium diagram for binary mixture	
3.	Batch Distillation,	
4.	Sieve Plate Distillation,	
5.	Packed Bed Distillation Column, Flooding and Loading in Packed Tower,	
6.	Water Cooling Tower,	
7.	Liquid-Liquid Extraction,	

8.	Rotating Disk Contactor,	
9.	Liquid-Liquid Extraction in Sieve Plate Column,	
10.	Drying Characteristics of Wet Solids in Flowing Air, Rotary Drier (Hold-Up), Rotary Drier (Drying Characteristics of Wet Solids), Gas-Solid Adsorption	

Text Book:

1. R. E. Treybal, Mass Transfer Operations, McGraw Hill Education, 2017.

Reference:

2. W. L. McCabe, J. C. Smith and P. Harriott, Unit Operations of Chemical Engineering, McGraw Hill Education, 2017.

Department Electives	
Department Electives	4. Bio Chemical Engineering 5. Process Optimization 6. Process Integration System and Design

Course Type	**Course Code**	**Name of Course**	**L**	**T**	**P**	**Credit**
DE		Biochemical Engineering	3	1	0	3
Course Objective						
1. To introduce the concepts of biology and chemical engineering that are necessary for biochemical process development to the students.						
Learning Outcomes						

1. Understand the definitions and scope of Biotechnology, Biochemical engineering and Bioprocess engineering.
2. Understand the need for chemical engineers to have fundamental knowledge in biology to be a successful biochemical engineer.
3. Understand enzyme kinetics, Inhibitions, immobilization methods, effect of immobilization on kinetics of enzymes.

Unit No.	Topics to be Covered	Learning Outcome
1.	Overview of Biotechnology; Kinetics of Enzyme Catalysis; Immobilized Enzymes: effects of intra and inter-phase mass transfer on enzyme kinetics; Major Metabolic Pathways.	Understand the definitions and scope of Biotechnology, Biochemical engineering and Bioprocess engineering Understand enzymes and cells as the major catalysts in bioprocesses.
2.	Bioenergetics, Glucose Metabolism, Biosynthesis; Microbial Growth: Continuum and Stochastic Models; Design, Analysis and Stability of Bioreactors.	Understand cell growth and their models, Understand enzyme kinetics, and Inhibitions.
3.	Kinetics of Receptor-Ligand Binding; Molecular Genetics and Regulation of Gene Expression; Purification and Bio-product Recovery; Manufacture of Biological Products.	Understand reactor design from bioprocess perspective. Understand separation processes from bioprocess perspective.
4.	Anaerobic digestion and fermentation for food Industry.	Understand Anaerobic digestion and fermentation aspects.

Text Book:

1. M.L. Shuler, and F Kargi, Bioprocess Engineering: basic concepts, Prentice Hall 2001.

Reference:

1. H.W. Blanch, and D.S. Clark, Biochemical Engineering, CRC Press 1997.

2. N.S. Mosier, and M.R. Ladisch, Modern Biotechnology: Connecting Innovations in Microbiology and Biochemistry to Engineering Fundamentals, Wiley-AIChE 2009.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE		Process Optimization	3	0	0	3

Course Objective

To introduce different types of optimization methods for chemical engineering processes

Learning Outcomes

1. Formulate objective function for a given problem
2. Solve unconstrained single and multi-variable optimization problems
3. Apply linear programming and nonlinear programming techniques

The Nature and Organization of Optimization Problems: What Optimization is all about, Why Optimize? Scope and Hierarchy of Optimization, Examples of applications of Optimization, The Essential Features of Optimization Problems, General Procedure for Solving Optimization Problems.

Analytical methods: Objective function, single variable optimization, multivariable optimization without and with constraints. Linear programming: graphical, algebraic, simplex methods, duality. Numerical search methods: one dimensional search, unrestricted, exhaustive search methods, interpolation methods. Multidimensional search methods without and with constraints. Variational methods and their applications.

Text Books:

1. Optimization of Chemical Processes, Edgar T.F. and D. M. Himmelblau, McGraw Hill, 2001, 2nd Edition.
2. Engineering Optimization: Theory and Practice, Singiresu S Rao, John Wiley & Sons Ltd., 2019, 5th Edition.

Reference Books:

1. Optimization: Theory and Practice, Mohan C. Joshi and Kannan M. Moudgalya, Alpha Science International Limited, 2004.
2. Convex optimization, Stephen Boyd, Lieven Vandenberghe, Cambridge University Press, 2004.
3. Applied Optimization with MATLAB Programming, Venkataraman P., Wiley, 2009, 2nd Edition.
4. Design of Thermal Systems, Stoecker W. F., McGraw-Hill, 2011, 3rd Edition.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE		Process Integration and System Design	3	0	0	3

Course Objective

1. This course is intended to provide basics of chemical process economics, design, use of pinch technology in Heat integration of process plants.

Learning Outcomes

1. Understand the steps in process development and integration
2. Understand components of Process integration: Process synthesis, analysis and optimization
3. Understand steps in process design
4. Understand Process flow sheets-Evaluation of process design
5. Hierarchy of steps in the process design and integration-Onion diagram
6. Understand approaches to process design- Unstructured and structured
7. Understand pinch technology as it applied to heat integration of chemical process plants.
8. Understand both graphical and numerical procedures for finding minimum energy, minimum area, and minimum units, minimum cost targets in heat integration.
9. Basics of Process economics
10. Use Aspen Plus for simulating process flow sheets.
11. Use Aspen Plus energy analyser and other software to develop targets for heat integration and design of heat exchanger networks.

Unit No.	Topics to be Covered	Learning Outcome
1.	Introduction to process design and integration	Understand the steps in process development and integration Understand components of Process integration: Process synthesis, analysis and optimization Understand steps in process design Understand Process flow sheets-Evaluation of process design
2.	Process Flow Sheet simulation in Aspen plus	Learn how to do simulations in aspen plus.

3.	Pinch technology and its application to heat integration	Understand Pinch technology, heat integration, Steps in heat integration using pinch technology
4.	Heat exchanger networks: Targeting of energy, area, number of units and cost (graphical and numerical methods of targeting)	Understand T-H diagrams, Composite curves, Energy targeting using graphical methods, Problem table algorithm, area targeting, units targeting and cost targeting
5.	Network Integration: Super targeting, maximum energy recovery, multiple utilities and multiple pinches, Grand Composite curve.	Trade-off between energy and cost of HENs. Grand composite curves
6.	Analysis and design for maximum energy recovery, Loop Breaking & Path Relaxation	Design of HENs with minimum cost
7.	Process Economics	Principles, cost estimation, depreciation and total annualized cost, cost indices, rate of return, payback period

ELECTIVE- I	
Elective - I	7. Petroleum Exploration 8. Bio Energy 9. Wastewater Management 10. Management Techniques for Industrial Sector 11. Principles of Energy Conversion

Course Type	Course Code	Name of Course	L	T	P	Credit
ELECTIVE-I	PE 30013	Petroleum Explorations	3	0	0	3

Principles and methods of geological and geochemical exploration, pathfinders and trace elements in rocks and soils. Primary and secondary dispersion patterns, geochemical anomalies and their interpretation Geophysical Explorations: Gravity method; Magnetic method; Electrical Methods; Seismic Methods: Field procedure, Data acquisition, Data processing, Data processing sequence, Advanced processing, Data processing using software; Interpretation of images, Detection of hydrocarbons.

Books:

Course Type	Course Code	Name of Course	L	T	P	Credit
ELECTIVE-I	PE 30014	Bio Energy	3	0	0	3

Course Objective

1. The course will instruct students the science and technology of biofuels and bioenergy.
2. It will give an overview of biomass feedstock and its availability, various technological practices in the generation of biofuels and bioenergy.

Learning Outcomes

1. Students will learn about the benefits of various feedstocks and the processes involved in the biofuel generation.
2. Importance of the available natural resources as the sustainable, efficient, and cost-effective bioenergy sources will be discussed.

Unit No.	Topics to be Covered	Learning Outcome
1.	Introduction to Bioenergy; Current status, merits & demerits. Feedstock,: starch, oilseed, lignocellulosic and algae based, fuel logistics of Biomass.	Students will get an overview of bioenergy, types of biofuels and their sources.
2	Biological conversion technologies, enzyme hydrolysis, ethanol fermentation, comparisons of fossil fuels and bio fuels.	Students will understand the technical aspects of biomass conversion technologies.
3.	Fundamentals of anaerobic digestion, Microbial fuel cells, Bio-refinery. Economic, Social and Ecological Impacts of Bioenergy at Local, National and Global Levels.	Students will learn the importance of microbes in biofuel processes. Learn economic, social and ecological impacts of bioenergy.
4.	Life cycle assessment, current and emerging challenges to bioenergy development, Govt. policies and standards.	Students will learn about different bioenergy policies and the challenges involved.

Text Book:

1. Y. Li, and S. K. Khanal, Bio Energy: Principles & Applications: Wiley-Blackwell 2016.

2. S. Lee, and Y T Shah, Bio Fuels and Bio Energy: Processes and Technologies, CRC Press, 2012.

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective: I	CH 30010	Wastewater Management	3	0	0	3

Course Objective

1. The course provides a thorough understanding of wastewater management to convert the "burden (i.e., wastewater)" into "resources (i.e., clean water, energy, and fertilizer).

Learning Outcomes

1. Understand the categorization of wastewater, and its sources with various characterization methods.
2. Learn the fundamental aspects of physical, chemical, and biological processes for wastewater treatment.
3. Convert the "burden (i.e., wastewater)" into "resources (i.e., clean water, energy, and fertilizer) using wastewater management techniques.
4. Select suitable treatment strategy to target specific contaminants.

Unit No.	Topics to be Covered	Learning Outcome
1.	Introduction to water and wastewater engineering, Methods for characterizations of wastewater properties.	Understand categorization of wastewater, their sources along with various characterization methods.
2.	Physical, chemical and biological process for wastewater treatment, primary, secondary and tertiary treatment including suspended growth and attached growth methods.	Learn the fundamental aspects of physical, chemical, and biological processes for wastewater treatment.
3.	Advanced oxidations process for removal of recalcitrant components in wastewater, nutrient removal, sludge treatment and its removal, progress in zero discharge techniques.	Learn AOPs and their application in the treatment of recalcitrant pollutants along with sludge management.

4.	Case studies related to treatment of Industrial and municipal effluents, standards and regulations.	Learn various standards and regulations.
5.	Up flow anaerobic sludge blanket, issues related to water treatment in large size industrial set up, clearing of water bodies/rivers in the context of Ganga Action plan and other initiatives.	Learn about anaerobic sludge blanket reactor and Ganga Action plan.

Text Book:

1. W. Eckenfelder (Jr.) Industrial Water Pollution Control, McGraw Hill (1999).

2. G. Tchobanoglous., L. Burton, and H.D. Stensel, Wastewater Engineering Treatment and Reuse (Metcalf & Eddy), McGraw Hill (2002).

Reference:

1. H.S. Peavy, D. R. Rowe, G. Tchobanoglous, Environmental Engineering, Mcgraw-Hill (1985).

2. A. P. Sincero and G.A. Sincero, Physical-Chemical Treatment of Water and Wastewater, CRC press (2002).

Course Type	Course Code	Name of Course	L	T	P	Credit
Elective: 1		Principles of Energy Conversion	3	0	0	3

Pre-requisite courses

Basics of Thermodynamics.

Course Objective

1. Compare competing energy conversion technologies on an economic and efficiency basis.
2. Be familiar with basic principles of thermal, mechanical, chemical, nuclear, and solar energy conversion.
3. Be familiar with thermodynamic processes and power cycles (thermal and mechanical energy).
4. Be familiar with basic principles of energy storage.

Learning Outcomes

1. At the end of the course students will learn and understand the basic principle involved in energy conversion.
2. Students will get to know about energy conversion efficiency.
3. Students will learn about thermodynamic processes and power cycles.
4. Students will get to know about Thermal, chemical, nuclear, wind energy conversion principles.
5. Students will get to know about the basic principles of energy storage.

Unit No.	Topics to be Covered	LearningOutcome
1	Energy, Growth Rate & Energy Economics energy, energy classification, units, energy conversion, conversion efficiency · energy information and perspectives.	Students will learn and understand the basic principle involved in energy conversion.
2	Thermal-to-Mechanical Conversion · Early engines & efficiency · Thermodynamics & power cycles & efficiency · Rankine Cycle · Brayton Cycle	Students will learn about thermodynamic processes and power cycles.

3	Chemical-to-Thermal Conversion · principles of combustion, fuels: coal, petroleum, gas.	Students will be familiar with basic principles of thermal, mechanical, chemical, nuclear, and solar energy conversion.
4	Electromagnetic-to-Thermal Conversion principles of solar insolation · solar collectors · thermal energy storage.	
5	Electromagnetic-to-Electrical Conversion principles of photovoltaics.	
6	Nuclear-to-Thermal Conversion · principles of nuclear energy · pressurized water reactors · boiling water reactors · boiling water, graphite-moderated reactors · Gen-IV reactors.	
7	Mechanical-to-Mechanical Conversion · principles of wind energy.	
8	Chemical-to-Electrical Conversion · principles of fuel cells.	
9	Introduction to Energy Storage · hydrogen · flow batteries · compressed gas, flywheel.	Students will be familiar with basic principles of energy storage.

Text Books:

1. Energy Conversions by Kenneth Weston.
2. Principles of Energy Conversion by Culp, McGraw-Hill Companies.
3. Lecture notes.

Reference Books

1. BEI International, Hambling, P., (Ed.), Modern Power Station Practice: Nuclear Turbines, and Associated Plant, Pergamon Press, 1992.
2. Drbal, L. F., Boston, P. G., Westra, K. L., Black and Veatch, Power Plant Engineering, Kluwer Academic, 1995.
3. Elliott, T. C., Chen, K., and Swanekamp, R., Standard Handbook of Power Plant Engineering, McGraw-Hill Professional, 2nd ed., 1997 El-Wakil, M. M.,
4. Power Plant Technology, McGraw-Hill, 1984. Jog, M., Hydro-electric and Pumped Storage Plants, John Wiley, 1989. Fritz, J. J., Small and Mini Hydropower Systems, McGraw-Hill, 1984. Central Board for Irrigation and Power (CPIB), India, Design and Construction Features of Selected Dams in India, 1983. Borbely, Anne-Marie, and Kreider, Jan J., (Eds.), Distributed Generation: The Paradigm for the New Millennium, CRC Press, 2003. Larminie, J., and Dicks, A., Fuel Cell Systems Explained, John Wiley, 2003. Vielstich, W., Lamm, A., and Gasteiger, H., Handbook of Fuel Cells: Fundamentals, Technology, Applications, John Wiley, 2003 Appleby, A. J., and Foulkes, F. R. Fuel Cell Handbook, van Nostrand Reinhold, 1996. Harrison, R., Hau, E., and Snel, H., Large Wind Turbines: Design and Economics, John Wiley, 2001.)