Course Curriculum Structure and Syllabi

for

Bachelor of Technology

in

Chemical Engineering

(Second Year Onwards)

Department of Chemical Engineering

National Institute of Technology Hamirpur

Hamirpur – 177 005 (India)

Curriculum for B Tech Programme

Course No.	Semester 3	Credits	Course Type
BS/Engg	Basic Sciences	3	Discipline core
	Engineering Courses	14	Discipline core
	Engineering Course (Lab)	2	Discipline core
Discipline Workshop	Basic Engineering Skills	1	Discipline core
	Total	**20**	

Course No.	Semester 4	Credits	Course Type
	Engineering Course	13	Discipline core
	Engineering Course	3	Discipline Elective
	Engineering Course (Lab)	3	Discipline core
	LA/CA	1	Institute Elective
	Total	**20**	

Curriculum for B Tech Programme

Second Year															
3rd Semester							4th Semester								
SN	Code	Subject	L	T	P	C	SN	Code	Subject	L	T	P	C
1	CH-211	Numerical Methods in Chemical Engineering	3	0	0	3	1	CH-221	Heat Transfer	3	1	0	4
2	CH-212	Fluid Mechanics	3	1	0	4	2	CH-222	Chemical Engineering Thermodynamics-II	3	0	0	3
3	CH-213	Chemical Engineering Thermodynamics-I	3	0	0	3	3	CH-223	Process Equipment Design-I	3	0	0	3
4	CH-214	Chemical Process Calculations	3	1	0	4	4	CH-224	Chemical Technology	3	0	0	3
5	CH-215	Mechanical Operation	3	0	0	3	5	CH-225	Heat Transfer Lab	0	0	2	1
6	CH-216	Fluid Mechanics Lab	0	0	2	1	6	CH-226	Thermodynamics Lab	0	0	2	1
7	CH-217	Mechanical Operation Lab	0	0	2	1	7	CH-227	Chemical Technology Lab	0	0	2	1
8	CH-218	Computational Lab	0	0	2	1	8	CH-241/242/243/244	Discipline Elective (I)	3	0	0	3
							9	SA-201/202/203/204/205/206/207/208/209	LA/CA (NSS/NCC/Prayas etc)				1
		Total =				20			Total =				20

Discipline Elective (I)

1. CH-241: Solid Waste Management (3)
2. CH-242: Process Instrumentation (3)
3. CH-243: Industrial Safety and Hazard Management (3)
4. CH-244: Energy Resources and Utilization (3)

Curriculum for B Tech Programme

Course No.	Semester 5	Credits	Course Type
	Open Elective	3	Institute Electives
	Engineering Course	**12/10**	Discipline core
	Engineering Course	3	Discipline Elective
	Engineering Course (Lab)	2	Discipline core
	HSS Course (**Non Circuital branches)**	**0/2**	Institute Core
	Total	**20**	
Course No.	**Semester 6**	**Credits**	**Course Type**
	Engineering Course	**10/8**	Discipline Core
	Engineering Course	6	Discipline Elective
	Engineering Course	2	Stream Core
	Engineering Course (Lab)	2	Discipline Core
	HSS Course **(Circuital branches)**	**0/2**	Institute Core
	Total	**20**	

Third Year														
5th Semester							6th Semester							
SN	**Code**	**Subject**	**L**	**T**	**P**	**C**	**SN**	**Code**	**Subject**	**L**	**T**	**P**	**C**
1	CH-311	Mass Transfer-I	3	0	0	3	1	CH-321	Mass Transfer-II	3	1	0	4
2	CH-312	Chemical Reaction Engineering-I	3	1	0	4	2	CH-322	Chemical Reaction Engineering-II	3	0	0	3
3	CH-313	Process Dynamics and Control	3	0	0	3	3	CH-323	Transport Phenomena	3	0	0	3
4	CH-314	Chemical Reaction Engineering Lab	0	0	2	1	4	CH-324	Mass Transfer Lab	0	0	2	1
5	CH-315	Process Dynamics and Control Lab	0	0	2	1	5	CH-325	Energy Technology Lab	0	0	2	1
6	CH-351/352/353/354	Discipline Elective - II	3	0	0	3	6	CH-341/342/343/344/345	Discipline Elective (III)	3	0	0	3
7	CH-301/302/303	Open Elective	3	0	0	3	7	CH-361/362/363/364/365	Discipline Elective (IV)	3	0	0	3
8	HS-311	HSS Course (Non circuital branches)	2	0	0	2	8	CH-381	Stream Core-I	2	0	0	2
		Total =				**20**			**Total =**				20

Curriculum for B Tech Programme

Discipline Elective (II)

1. CH-351: Thermodynamics of Phase and Chemical Equilibria (3)
2. CH-352: Fuel Cells and Hydrogen Energy (3)
3. CH-353: Food Science and Engineering (3)
4. CH-354: Fluidization Technology (3)

Open Elective

1. CH-301: Industrial Safety and Hazard Management (3)
2. CH-302: Water and Wastewater Treatment Technologies (3)
3. CH-303: Energy Resources and Utilization (3)

Discipline Elective (III)

1. CH-341: Advance Process Control (3)
2. CH-342: Soft Computing Methods in Chemical Engineering (3)
3. CH-343: Fertilizer Technology (3)
4. CH-344: Reservoir Engineering (3)
5. CH-345: Biochemical Engineering (3)

Discipline Elective (IV)

1. CH-361: Colloid and Interface Science (3)
2. CH-362: Principles of Non-Newtonian Fluid Mechanics (3)
3. CH-363: Nanomaterials and Nanofabrication (3)
4. CH-364: Introduction to Molecular Simulation (3)
5. CH-365: Computational Fluid Dynamics (3)

Stream Core-I

1. CH-381: Energy Technology

Course No.	Semester 7	Credits	Course Type
	Engineering Course	9	Discipline Core
	Engineering Course	3	Discipline Elective
	Engineering Course	4	Stream Core
	Engineering Course (Lab)	2	Discipline Core
Vocational Training	Engineering Course	2	Discipline Core
	Total	**20**	

Course No.	Semester 8	Credits	Course Type
	UG Project*	12/12	Discipline elective
	Free Elective/Engineering Course/Open Elective Course (Courses available in other departments in the even semester)	**6**	Free Electives/Stream Elective (offered by Department/Institute Elective (Open Elective)
General Proficiency	Holistic Assessment	2	Institute Core
	Total	**20**	

***** Students **opting for internship** will **complete the UG project** and the remaining credit requirements will be by fulfilled by opting **Free Elective Courses**

Fourth Year													
7th Semester							8th Semester						
SN	**Code**	**Subject**	**L**	**T**	**P**	**C**	**SN**	**Code**	**Subject**	**L**	**T**	**P**	**C**
1	CH-411	Process Plant Design and Economics	3	0	0	3	1	CH-461/462/463/464	Stream Electives-I	3	0	0	3
2	CH-412	Process Equipment Design-II	3	0	0	3	2	CH-481/482/483/484	Stream Electives-II	3	0	0	3
3	CH-413	Process Modeling and Simulation	3	0	0	3	3	CH-498	Holistic Assessment				2
4	CH-414	Process Simulation Lab	0	0	2	**1**	4	CH-499	UG Project				12
5	CH-415	Industrial Pollution Abatement Lab	0	0	2	1							
6	CH-431/432/433/434/435/436	Discipline Elective (V)	3	0	0	**3**							
7	CH-451	Stream Core-II	2	0	0	2							
8	CH-471	Stream Core-III	2	0	0	2							
9		Vocational Training*	0	0	2	2							
		Total =				**20**			**Total =**				20

*The students should undergo vocational training during summer vacations after sixth semester

Discipline Elective (V)

1. CH-431: Optimization of Chemical Processes (3)
2. CH-432: Polymer Science and Engineering (3)
3. CH-433: Biomass Valorization Technologies (3)
4. CH-434: Introduction to Statistical Thermodynamics (3)
5. CH-435: Novel Separation Processes (3)
6. CH-436: Petrochemical Technology (3)

Stream Core-II

1. CH-451: Industrial Pollution Abatement (2)

Stream Core-III

2. CH-471: Petroleum Refining (2)

Stream Elective-I

1. CH-461: Process Intensification (3)
2. CH-462: Chemical Reactor Analysis and Design (3)
3. CH-463: Water and Wastewater Treatment Technologies (3)
4. CH-464: Advance Transport Phenomena (3)

Stream Elective-II

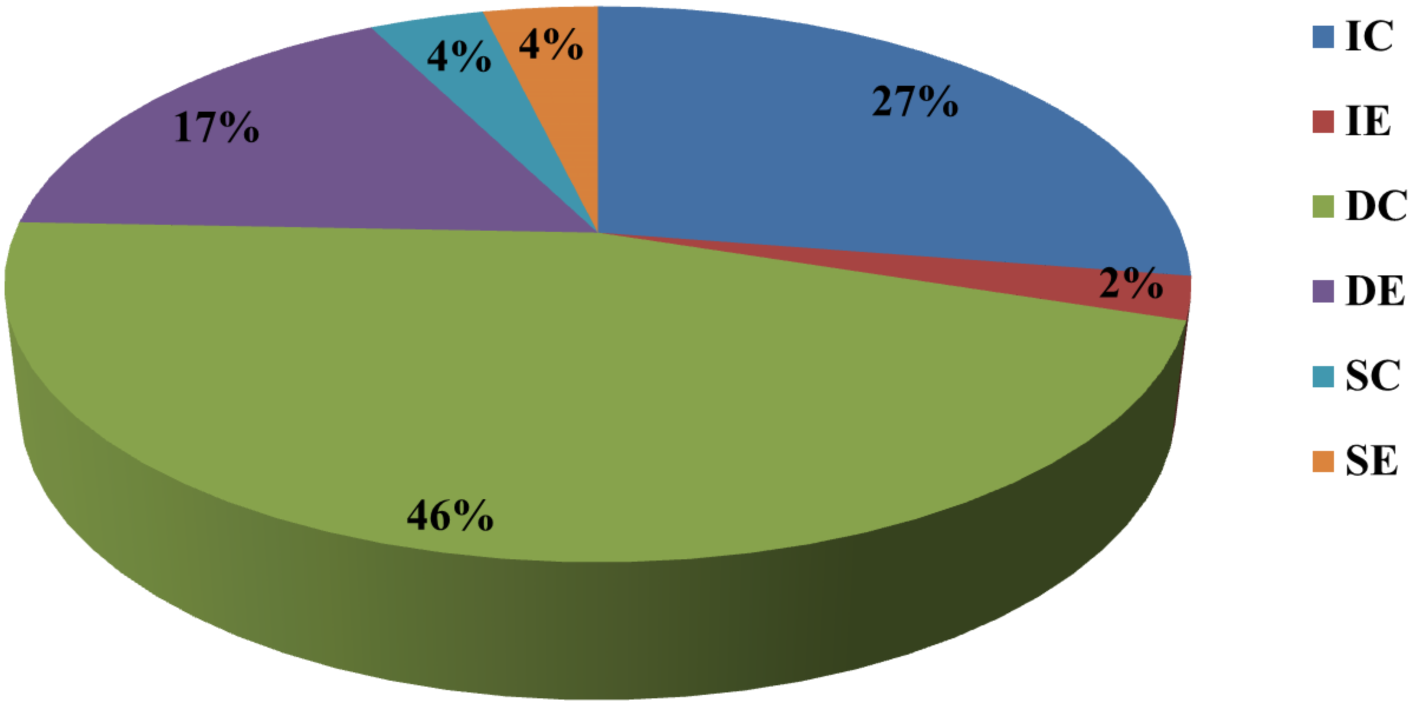
1. CH-481: Bioprocess Engineering (3)
2. CH-482: Analytical and Characterization Techniques (3)
3. CH-483: Introduction to Plastic Materials (3)
4. CH-484: Multiphase Flow (3)

Types of Courses and credits in each Semester

	Semester								
Types of Courses	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**Total**
IC	20	20	0	0	2	0	0	2	44
IE	0	0	0	1	3	0	0	6*	4-10*
DC	0	0	20	16	12	12	13	0	73
DE	0	0	0	3	3	6	3	12	27
SC	0	0	0	0	0	2	4	0	6
SE	0	0	0	0	0	0	0	6*	0-6*
Total	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**160**
Total **160**									

* Students are free to choose any combination out of Free Electives, IE and SE for 6 credits

Share of Credits based on the Requirement of the Programme



SEMESTER-III

Course Name: **Numerical Methods in Chemical Engineering** Course Code: **CH-211** Course Type: **Discipline Core**		
Contact Hours/Week: **3L**		Course Credits: **03**
Course Objectives: • To understand and learn various numerical techniques to solve mathematical problems representing Chemical engineering, physical and real-life problems.		
Unit Number	**Course Content**	**Lectures**
UNIT-01	**Linear Algebraic Equations:** Introduction, Gauss-Elimination, Gauss-Siedel and LU Decomposition methods, Thomas' algorithm.	**06L**
UNIT-02	**Eigen Values and Eigen Vectors of Matrices:** Introduction, Fadeev-Leverrier's method, Power method, Householder's and Givens' method.	**06L**
UNIT-03	**Nonlinear Algebraic Equations:** Single variable and multivariable successive substitution method, single variable and multivariable Newton-Raphson technique, and Polynomial root finding methods.	**06L**
UNIT-04	**Function Approximation:** Least squares curve fit, Newton's interpolation formulae, Lagrangian interpolation, Pade approximation, Cubic spline approximation. **Integration formulae:** Trapezoidal rule, Simpson's rule. Ordinary Differential Equations - Initial Value Problems: Explicit Adams-Bashforth technique, Implicit Adams-Moulton technique, Predictor-corrector technique, Runge-Kutta methods, Stability of algorithms	**09L**
UNIT-05	**Ordinary Differential Equations - Boundary Value Problems:** Finite difference technique, Orthogonal Collocation (OC), Shooting Techniques. **Partial Differential Equations:** Partial Differential Equations (PDE) - Classification of PDE, Finite difference technique (Method of lines), Orthogonal collocation. Case Studies. Use of spreadsheets and MATLAB in Chemical Engineering.	**09L**
Course Outcomes Upon successful completion of the course, the student will be able to, CO1: Understand the errors, source of error and its effect on any numerical computations and also analysis the efficiency of any numerical algorithms. CO2: Learn how to obtain numerical solution of nonlinear equations using bisection, secant, Newton, and fixed-point iteration methods. CO3: Solve system of linear equations numerically using direct and iterative methods. CO4: Understand how to approximate the functions using interpolating polynomials. CO5: Learn how to solve definite integrals and initial value problems numerically.		
Books and References 1. Applied Numerical Analysis by F .C. Gerald and O. P. Wheatley, 7thEdition, Pearson, 2003. 2. Numerical Methods for Scientific and Engineering Computation by K. M. Jain., K. R. S. Iyengar and K. R. Jain, 6thedition, New Age International Publishers, 2012. 3. Numerical Methods for Engineers by S. C. Chapra, 7th edition, McGraw-Hill Higher Education, 2014. 4. Numerical Methods for Mathematics, Science and Engineering by H. J. Mathew, 2nd edition, Prentice Hall, 1992. 5. Numerical Analysis by L. R. Burden and D. J. Faires, 9th edition, Brooks/Cole, 2011. 6. Elementary Numerical Analysis by K. Atkinson and H. Han H, 3rd edition, John Willey & Sons, 2004.		

Course Name: **Fluid Mechanics**
Course Code: **CH-212**
Course Type: **Discipline Core**

Contact Hours/Week: **3L+1T** Course Credits: **04**

Course Objectives:

- To understand basic principles of fluid mechanics and their application in solving engineering problems.
- To teach fundamental concepts in fluid mechanics and apply them to real problems.
- To develop and use momentum and energy conservations laws and Bernoulli's equation.
- To explain basics behind various measurements, pipe fitting, valves, pump types and centrifugal pump.

Unit Number	Course Content	Lectures
UNIT-01	**Introduction:** Ideal and real fluids, specific weight, mass density and specific gravity, viscosity and its measurements, pressure and temperature dependence of viscosity, surface tension and capillarity, Newtonian and non-Newtonian fluids, dimensional analysis.	**06L**
UNIT-02	**Fluids Static:** Pressure, hydrostatics law, Pascal's law, manometers and pressure measurement, forces on inclined plane and curved submerged surfaces.	**04L**
UNIT-03	**Fluids Kinematics and Dynamics**: Classification of fluid flows, Eulerian and Lagrangian approach, substantial derivative, laminar and turbulent flow, Stream function, potential function, vortex flow (free and forced). Continuity equation, Navier-Stoke's equation, Bernoulli's equation and its application, correction factors, energy and hydraulic grade lines. flow and velocity measurement devices: Pitot tube, hot wire anemometer, Vena-contracta, notches and weirs, orifice meter, venture meter, rotameter.	**09L**
UNIT-04	**Incompressible Viscous Flow:** General characteristics of pipe flow-laminar, turbulent, entrance region, fully developed flow. Hagen-Poiseuille equation, shear stress distribution and velocity profiles, major and minor losses in pipes, fittings, noncircular ducts, friction factor, pipe roughness, Moody chart, Boundary layer theory, drag force, lift and drag coefficients, drag on flat plate, circular cylinder and sphere.	**09L**
UNIT-05	**Pumps and compressors**: Classification and working of pumps: centrifugal, reciprocating, piston, plunger, gear and diaphragm pumps, Work and power input, cavitation, NPSH, maximum suction lift, specific and minimum speed, pump losses and efficiencies, Multistage pumps, fans, blowers and compressors	**08L**

Course Outcomes

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

CO1: Apply basic concepts of fluid mechanics in manometers, flow and velocity measurements.
CO2: Develop dimensionless groups and describe turbulent flow.
CO3: Apply principles of conservation of mass, momentum and energy and Bernoulli's equation.
CO4: Calculate losses in pipes and fittings and do basic calculations on pumps.

Books and References

1. Unit Operations of Chemical Engineering by J.C. Smith, W.L. McCabe, and P.H. Harriot, McGraw-Hill, 2017.
2. Fluid Mechanics and Fluid Power Engineering by D.S. Kumar, S. K. Kataria and Sons, 1987.
3. Fluid Mechanics by F.M. White, McGraw-Hill, 1991.
4. Fluid Mechanics: Fundamentals and Applications by J.M. Cimbala, and Y.A. Cengel, McGraw-Hill, 2019.
5. Hydraulics and Fluid Mechanics by P.N. Modi, and S.M. Seth, Delhi Standard Publishers, 2019.

Course Name: **Chemical Engineering Thermodynamics-I**
Course Code: **CH-213**
Course Type: **Discipline Core**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives:

- To impart knowledge about the basic concepts of chemical engineering thermodynamics.
- To introduce the fundamental concepts relevant to different chemical process.
- To apprise students of various laws of thermodynamics and their application

Unit Number	Course Content	Lectures
UNIT-01	**Fundamental Concepts and Definitions:** Closed, open and isolated system, intensive and extensive properties, path and state functions, reversible and irreversible process, zeroth and first laws of thermodynamics, internal energy, enthalpy, heat capacity, heat and work, steady state energy, applications.	**06 L**
UNIT-02	**P-V-T Behaviour of Pure Substances:** Ideal gases, equations of state, Van der Waals, Redlich-Kwong and Virial equations, principle of corresponding states, critical and pseudo critical properties, compressibility charts, steam table, generalized correlations for gases and liquids.	**07 L**
UNIT-03	**Second Law of Thermodynamics:** Limitations of first law, general statements of second law, concept of entropy, calculation of entropy changes, Carnot's principle, absolute scale of temperature, Clausius inequality, entropy and irreversibility, statistical explanation of entropy, third law of thermodynamics, available energy and exergy.	**08 L**
UNIT-04	**Heat Effects in Chemical Reactions:** Standard heat of formation, combustion and reaction, effect of temperature on heat of reaction, temperature of reactions, adiabatic reaction temperature.	**05 L**
UNIT-05	**Refrigeration and Liquefaction:** COP, vapour compression cycles, Carnot cycle, air compression, general properties of refrigerant, choice of refrigerant, absorption refrigeration, heat pump, Joule-Thomson expansion and liquefaction processes.	**06 L**
UNIT-06	**Power Cycles:** Rankine cycle, internal combustion engine cycles, gas-turbine power plant cycle.	**04 L**

Course Outcomes

Upon successful completion of the course, the students will be able to,
CO1: Identify and calculate the thermodynamic properties of pure substances.
CO2: Describe the different thermodynamic aspects based on fundamental concepts.
CO3: Apply principle of thermodynamics for analysis of various processes.
CO4: Assess the importance of applications of thermodynamic laws in related fields.

Books and References

1. Chemical Engineering Thermodynamics by Y.V.C. Rao, Universities Press, Hyderabad, 1997.
2. Introduction to Chemical Engineering Thermodynamics by J.M. Smith, H.C. VanNess, and M.M. Abbott, Tata McGraw Hill, 2010.
3. Chemical and Process Thermodynamics by B.G. Kyle, Prentice Hall PTR, New Jersey, 1999.
4. A Text book of Chemical Engineering Thermodynamics by K.V. Narayanan, Prentice Hall, 2013.
5. Thermodynamics: An Engineering Approach by Y.A. Cengel, and M.A. Boles, Tata McGraw-Hill, 2008.

Course Name: **Chemical Process Calculations** Course Code: **CH-214** Course Type: **Discipline Core**	
Contact Hours/Week: **3L+1T**	Course Credits: **04**

Course Objectives:

- To understand the basic units of different variables used in various chemical processes and their conversions.
- To understand various physical properties and their behavior with the process conditions.
- To enable students to formulate and solve material and energy balances for chemical processes.

Unit Number	Course Content	Lectures
UNIT-01	**Stoichiometry:** Units and dimensions, dimensional homogeneity, stoichiometric principles, composition relations, density and specific gravity.	**04L**
UNIT-02	**Ideal Gases and Vapor Pressure:** Behaviour of ideal gases, application of ideal gas law, volume changes with change in composition of gaseous mixtures, effect of temperature on vapor pressure, vapor pressure plots vapor pressure of immiscible liquids-solutions.	**06L**
UNIT-03	**Humidity and Solubility:** Humidity, relative humidity, saturation, condensation, wet and dry bulb thermometry, Adiabatic saturation temperature, psychrometric chart, solubility and crystallization, dissolution, solubility of gases.	**06L**
UNIT-04	**Material Balance:** Degree of freedom, material balances for systems without chemical reactions, systems with by-pass, recycle and purge material balance with chemical reaction, species and elemental balance.	**07L**
UNIT-05	**Energy Balance:** Steady state energy balance for non-reacting systems, mechanical energy balance, enthalpy balances, heat capacity of gases, liquids and solutions, heat of fusion and vaporization, energy balance for reacting system, calculations and application of heat of reaction and heat of formation, combustion, enthalpy-concentration charts, combustion of solids, liquids and gaseous fuels.	**07L**
UNIT-06	**Simultaneous Balances:** Problems related to simultaneous steady state energy and material balance, unsteady and material balance, simultaneous material and energy balance.	**06L**

Course Outcomes

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

CO1: Understand the unit, dimensions, and their conversion.

CO2: Describe and solve material and energy balances separately and simultaneously of a given process.

CO3: Understand the ideal and real behavior of gases, vapors and liquids.

CO4: Use of psychometric charts and determines the properties of air.

Books and References

1. Basic Principles and Calculations in Chemical Engineering by D.M. Himmelblau, and J.B. Riggs, 8th edition, Prentice Hall India, 2014.
2. Elementary Principles of Chemical Processes by R.M. Felder, R.W. Rousseau, and L.G. Bullard, 4th edition, John Wiley& Sons, 2011.
3. Chemical Process Principles (Part-I): Material and Energy Balances by O.A. Haugen, K.M. Watson, and R.A. Ragatz, 2nd edition, John Wiley& Sons, 2004.
4. Stoichiometry by B.I. Bhatt, and S.B. Thakore, 5th edition, McGraw Hill, 2017.

Course Name: **Mechanical Operation**
Course Code: **CH-215**
Course Type: **Discipline Core**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives:

- To impart knowledge about various operations carried out on solids in chemical industries
- To introduce the fundamental of various aspects of solid handling and fluid-solid interaction
- To enable the student to understand working principles of various industrial operations viz. clarification, thickening, sedimentation, handling and storage of solid materials

Unit Number	Course Content	Lectures
UNIT-01	**Size Reduction and Screening:** Particle size and shape, particle mass, size and shape distributions, measurement and analysis, concept of average diameter, size reduction, crushing, grinding and law of grindings, screening equipment, capacity and effectiveness of screen, effect of mesh size on capacity of screen	**10L**
UNIT-02	**Settling:** Flow around a single particle, drag force and drag coefficient, settling velocity of particles in a fluid, hindered and free settling of particles, gravity sedimentation, thickening and clarification, flotation, magnetic separation	**06L**
UNIT-03	**Filtration:** Classification of filters, various types of cake filters, principle of cake filtration, clarification filters, liquid clarification, centrifugal settling process	**06L**
UNIT-04	**Agitation and Mixing:** Agitation of liquids, axial flow impellers, radial flow impellers, velocity and power consumption of agitated vessels, blending & mixing	**03L**
UNIT-05	**Fluidization:** Packed beds, bed porosity, flow through a bed of particles, fluidization & fluidized bed, conditions for fluidization minimum velocity, types of fluidization	**06L**
UNIT-06	**Solid Handling:** Flow of solid by gravity, transport of solids by screw /belt conveyers, cyclones, bag filters, electrostatic precipitators, particulate collection system	**05L**

Course Outcomes

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

CO1: Identify the key problems associated with operation involving fluid-solid interaction

CO2: Describe various types of equipment used in size reduction, screening, solid-solid and fluid-solid separation, transportation of solids etc.

CO3: Apply principles of fluidization, surface energy, drag forces and other forces for solid feed processing in chemical industries

Books and References

1. Unit Operations of Chemical Engineering by J.C. Smith, W.L. Mccabe, and P.H. Harriot, McGraw Hill, 2001.
2. Mechanical Operation for Chemical Engineers by B.C. Bhattacharya, and C.M. Narayanan, Khanna Publishers, 1990.
3. Perry’s Handbook of Chemical Engineering by D.W. Green, and R.H. Perry, McGraw Hill, 1997.
4. Unit Operations by G.G. Brown, CBS Publisher, 2004.
5. Chemical Engineering by J.M. Coulson, J.F. Richardson, and R.K. Sinnott, Butterworth-Heinemann, 2003.

Course Name: **Fluid Mechanics Lab**
Course Code: **CH-216**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives

- To measure velocity, pressure and friction loss in pipe
- To determine efficiency of various pumps
- To calibrate various flowmeters and verify Bernoulli's theorem
- To study flow characteristic visually in a pipe and around an obstacle

List of Experiments

1. To verify Bernoulli's equation experimentally.
2. To study the velocity distribution in a pipe and to compute the discharge by integrating the velocity profile.
3. To visualize different flow conditions and obtain the Reynolds number.
4. To calibrate Venturimeter, Orificemeter and Rotameter.
5. To find the friction factor in pipes of different diameters.
6. To determine the minor head loss coefficient for different pipe fittings.
7. To draw flow net for irrotational flow past a cylinder (or any other geometry) using Hale –Shaw apparatus.
8. To draw the characteristics curve of reciprocating pump and determine its efficiency.
9. To draw the characteristics curve of gear pump and determine its efficiency.
10. To draw the characteristics curve of jet pump and to determine its efficiency.
11. To draw characteristic curve of a centrifugal pump and determine its efficiency.
12. To study the pressure measurement
13. To estimate the kinematic viscosity using Redwood viscometer.

Course Outcomes

Upon successful completion of the course, the student will be able to,
CO1: Perform various measurements on pressure, velocity, losses in pipes and fittings.
CO2**:** Select a flow meter for design purpose.
CO3**:** Calculate power requirements and efficiency of various types of pumps.

Course Name: **Mechanical Operation Lab** Course Code: **CH-217**	
Contact Hours/Week: **2P**	Course Credits: **01**

Course Objectives

- To understand the importance of various mechanical operations used in process industry.
- To apply principles of basic sciences and chemical engineering for designing various size reduction, separation and conveying equipment.

List of Experiments

1. Power consumption and study of agitation and mixing characteristic of a fluid.
2. Drag coefficient determination using falling ball method.
3. Application of Cyclone Separator and determination of collection efficiency.
4. Application of Vibrating Screen and determination of screening efficiency.
5. Application of Plate and Frame Filter Press and estimation of specific cake and filter medium resistance.
6. Determination of specific cake and filter medium resistance in Rotary Vacuum Filter.
7. Determination of crushing efficiency of a Roller crusher.
8. Ball Mill and its applications.
9. Determination of separation efficiency of a Trommel Screen.
10. Transport applications of a Screw Conveyor.
11. Determination of crushing efficiency of a Jaw Crusher.

Course Outcomes

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

CO1: Apply the principles of unit operations through experimentation for separating solids from fluids

CO2**:** Demonstrate the ability to understand the various equipment used in chemical and allied industry

Course Name: **Computational Lab**
Course Code: **CH-218**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives

- Teach to convert chemical engineering problem into numerical code.
- To give insights of computational software and tools such as SCILAB, MATLAB & SIMULINK.
- To develop computer programs to solve chemical engineering problems.

List of Experiments

1. Introduction to programming with MATLAB/SCILAB to solve chemical engineering problems.
2. Bracketing methods to find out roots such as Bisection and False-position methods.
3. Open methods to find out roots such as Newton-Raphson and Secant methods.
4. Solution of linear algebraic equations and matrices using Gauss Elimination, Iterative methods such as Gauss-Seidel and Jacobi, etc.
5. Finding eigenvalues and eigenvectors.
6. Curve fitting and interpolation, cubic splines.
7. Numerical integration methods such as Trapezoidal rule and Simpson's rules.
8. Numerical differentiation with MATLAB.
9. Solutions of ordinary differential equations of initial value problems using Euler's method, Runge-Kutta methods etc.
10. Solutions of ordinary differential equations of boundary value problems using shooting methods etc.
11. Solving ODEs using finite-difference methods.
12. Solving PDEs using MATLAB.

Course Outcomes

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

CO1**:** Formulate various chemical engineering problems and apply numerical techniques to solve them.
CO2**:** Solve Linear and non-linear Algebric equations, ODE's and PDEs through MATLAB.
CO3**:** Analyze two-and three dimensional models through computations.

SEMESTER-IV

Course Name: **Heat Transfer**
Course Code: **CH-221**
Course Type: **Discipline Core**

Contact Hours/Week: **3L + 1T** Course Credits: **04**

Course Objectives

- To impart knowledge about the fundamentals of heat transfer mechanisms in fluids
- To enable the students about the applications in various design of heat transfer equipment in chemical industries.

Unit Number	Course Content	Lectures
UNIT-01	**Introduction:** General concepts on modes of heat transfer by conduction, convection and radiation and its applications.	**02 L**
UNIT-02	**Conduction:** Fourier law, thermal conductivity, one dimensional heat conduction with and without heat generation through plane walls, cylindrical and spherical surfaces, composite layers, thermal contact resistance, insulating materials: critical and optimum thickness, extended surfaces, fins and their practical applications, unsteady state heat transfer and lumped heat model.	**07 L**
UNIT-03	**Convection:** Heat transfer coefficients, natural and forced convection, hydrodynamic and thermal boundary layers, laminar and turbulent heat transfer inside and outside of tubes, dimensional analysis, individual and overall heat transfer coefficients, correlations of heat transfer coefficient, combined free and forced convection, boiling phenomena, classification of boiling, typical boiling curve, flow boiling, condensation phenomena, condensation of mixed and pure vapours, film wise and drop wise condensations.	**09 L**
UNIT-04	**Radiation:** Black body concept, Planck's law, Kirchoff's law, Wein's displacement law, Stefan-Boltzmann law, gray body, view factor, radiation heat transfer in black, diffuse and gray surfaces, radiation exchange between surfaces, radiation shield.	**06 L**
UNIT-05	**Heat Exchangers**: Classification and design criteria, types of heat exchangers: double pipe, shell and tube, and plate type, fouling factors. mean temperature difference, LMTD, temperature correction factor, effectiveness NTU.	**07 L**
UNIT-06	**Evaporation:** Types of evaporators, principle of evaporation and evaporators - single and multiple effects, capacity and economy, material and energy balance in evaporators, boiling point elevation.	**05 L**

Course Outcomes

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

CO1: Identify the modes of heat transfer mechanisms in fluids and solids.
CO2: Identify and evaluate the heat transfer coefficient for natural and forced convection
CO3: Evaluate the loss in radiation heat exchange between different surfaces
CO4: Apply principles of heat transfer in designing of heat exchangers and evaporators.
CO5: Assess the performance of heat exchangers and evaporators by numerical problems.

Books and References

1. Heat Transfer by J.P. Holman, 10th edition, McGraw Hill, 2009.
2. Heat Transfer: A Practical Approach by Y.A. Cengel, 2nd edition, McGraw Hill, New York, 2003.
3. Heat Transfer: Principles and Applications by B. K. Dutta, PHI Learning Private Limited, Delhi, 2001.
4. Unit Operations of Chemical Engineering by W.L. McCabe, J.C. Smith, and P. Harriott, McGraw Hill, 7th edition, 2005.
5. Process Heat Transfer by D.Q. Kern, McGraw Hill, New York, 2001.

Course Name: **Chemical Engineering Thermodynamics-II** Course Code: **CH-222** Course Type: **Discipline Core**		
Contact Hours/Week: **3L**		Course Credits: **03**
Course Objectives • To impart knowledge about the concepts of chemical engineering thermodynamics. • To introduce the fundamental concepts relevant to different chemical process for mixtures. • To enable the students to understand the factors that cause the thermodynamic challenges in different chemical industries		
Unit Number	**Course Content**	**Lectures**
UNIT-01	**Thermodynamic Properties of Fluids:** Maxwell relations, relationships among the thermodynamic properties of single phase systems, residual properties, residual properties from equations of state, two phase systems.	**06 L**
UNIT-02	**Thermodynamics of Flow Processes:** Compressible fluids, incompressible fluids, pump, compressors and ejectors, working principle and efficiency of pumps, compressors and ejectors.	**05 L**
UNIT-03	**Equilibrium and stability:** Criteria of equilibrium, chemical potential, application of equilibrium criteria, Clausius-Clayperon equation, criteria of stability, application of stability criteria, equation related to stability.	**08 L**
UNIT-04	**Phase Equilibria:** Critical phase equilibria, bubble point and dew point, fugacity, composition of phases at equilibria, fugacity of pure components, fugacity charts, effects of temperature on fugacity, Gibb's Duhem equation in terms of activity coefficients for two component system, relating activity coefficient with composition, theoretical calculation of activity coefficient, relation for excess free energy, thermodynamic consistency tests, Margule and Van Laar equation, various methods to calculate Van Laar and Margule's constants.	**10 L**
UNIT-05	**Chemical Reaction Equilibrium:** Reaction ordinate for single & multiple reactions, condition of equilibrium for a chemical reactions, standard states and Gibbs free energy, temperature dependence of the equilibrium constant, estimation of equilibrium rate constant, chemical equilibrium constant, homogeneous and heterogeneous gas phase reactions.	**07 L**
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Relate and understand the various thermodynamic properties. CO2: Describe the different criteria of equilibrium based on thermodynamics relations. CO3: Apply principle of thermodynamics laws to determine the different equilibrium states. CO4: Assess the importance of chemical reaction equilibrium concepts.		
Books and References 1. Chemical Engineering Thermodynamics by Y.V.C. Rao, Universities Press, Hyderabad, 1997. 2. Introduction to Chemical Engineering Thermodynamics by J.M. Smith, H.C. Van Ness, and M.M. Abbott, Tata McGraw Hill, 2010. 3. Chemical and Process Thermodynamics by B.G. Kyle, Prentice Hall PTR, New Jersey, 1999. 4. A Text book of Chemical Engineering Thermodynamics, K.V. Narayanan, PHI, 2013. 5. Thermodynamics and an Introduction to Thermo-statistics by H.B. Callen, John Wiley and Sons, 1985.		

Course Name: **Process Equipment Design-I**
Course Code: **CH-223**
Course Type: **Discipline Core**

Contact Hours/Week: **3L** — Course Credits: **03**

Course Objectives

- To understand various process codes and standards to perform process design/equipment design calculations.
- To address the stress and strain produced in different parts of the equipment such as shell, head, support, etc. due to operating conditions of the process.
- To perform process equipment, covering and support design calculations.

Unit Number	Course Content	Lectures
UNIT-01	**Equipment Design Preliminaries:** Principles involved in the design and construction of equipment, materials of construction, design codes, pressure, temperature, factor of safety, corrosion allowance, weld joint efficiency factor, design loadings, Poisson's ratio, dilation of pressure vessels, stress concentration, thermal stresses, criteria of failure.	**06 L**
UNIT-02	**Design of Pressure Vessels/Storage Tanks:** Introduction to Indian Standards for storage tanks and their use to design cylindrical and spherical vessels under internal pressure, fixed roof and open roof tanks, design of different heads such as flat cover head, conical head, torispherical head and ellipsoidal head.	**07 L**
UNIT-03	**Design of Non-standard Flange, Pipe Fitting and Joints:** Types of flange and selection, specification of standard flanges, design of non-standard flanges including gasket, design of bolts, screws, welded and riveted joints, design of different pipe fittings.	**06 L**
UNIT-04	**Design of Supports**: Design of skirt, lug and saddle supports for vertical and horizontal vessels.	**06 L**
UNIT-05	**Design of Thick-walled High-Pressure Vessels:** Stresses in a thick cylinder, theories of elastic failure.	**06 L**
UNIT-06	**Equipment Fabrication and Testing:** Design of welded joints, post weld treatment, inspection and non-destructive testing of equipment.	**05 L**

Course Outcomes

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

CO1: Apply the Indian Standards to perform process design/equipment design calculations.

CO2: Calculate stress and strain induced in different parts of the equipment such as shell, head, support, etc. due to operating conditions of the process.

CO3: Apply step-by-step mechanical design aspects to design any process equipment.

Books and References

1. Chemical Equipment Design by B.C. Bhattacharya, CBS Publisher, 1985.
2. Process Equipment Design by L.E. Brownell, and E.H. Young, John Wiley & Sons, 2009.
3. Joshi's Process Equipment Design by V.V. Mahajani, and S.B. Umarji, 5th edition, Laxmi Publications, 2016.
4. Chemical Engineering by R.K. Sinnot, J.M. Coulson, and J.F. Richardson, Vol.-6, Butterworth Heinemann, 1998.
5. Applied Process Design for Chemical and Petrochemical Plants by E.E. Ludwig, Vol. -1, 2 & 3, Gulf Publishing Company, 1995.

Course Name: **Chemical Technology** Course Code: **CH-224** Course Type: **Discipline Core**		
Contact Hours/Week: **3L**		Course Credits: **03**
Course Objectives • To expose students to understand the advancement in chemical process industries and its application to chemical engineering. • Improve their ability to read and abstract the process flow diagrams. • Equip themselves with different feed preparation, separation and purification steps involved in manufacture of organic and inorganic chemicals		
Unit Number	**Course Content**	**Lectures**
UNIT-01	**Natural Products Processing:** Gasification of coal and chemicals from coal, Fermentation process, Sugar Industries: Manufacture of raw and refined sugar, by products of sugar industry. Oils and Fats: Types of oil, different fatty acids, extraction of oil from seeds, oil purification, hydrogenation of oil. Manufacture of paints and varnishes, pigments.	**10 L**
UNIT-02	**Soaps and Detergents:** Types of soaps, soap manufacture, recovery and purification, manufacturing of detergents. **Pulp and Paper industry:** various pulping methods, recovery of chemicals from black liquor, manufacture of paper, quality improvement of paper.	**07 L**
UNIT-03	**Chlor-alkali Industries:** Manufacture of Soda ash, brine electrolysis, manufacture of caustic soda and chlorine in mercury cells, diaphragm cells, membrane cells, Bleaching powder.	**03 L**
UNIT-04	**Fertilizer Industries:** Ammonia, nitric acid, ammonium sulphate, ammonium chloride, urea Phosphorus, phosphoric acid, phosphatic fertilizers, calcium phosphate, ammonium phosphates, nitrophosphates, sodium phosphate, potassium chloride and potassium sulphate.	**07 L**
UNIT-05	**Acids:** Mining of sulphur and manufacture of sulphuric acid, hydrochloric acid, nitric acid. **Ceramic Industries:** Types and manufacture of cement, lime, gypsum, manufacture of glasses and special glasses, refractories.	**09 L**
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Understand the processes involved in manufacturing of various inorganic and organic chemicals. CO2: Prepare the process flow diagrams. CO3: Analyze important process parameters and engineering problems during production.		
Books and References 1. Shreve's Chemicals Process Industries by G.T. Austine, McGraw Hill. 2. Dryden's Outlines of Chemical Technology, G.M. Rao, and M. Sittig, East West Press, New Delhi. 3. Chemical Technology by G.N. Pandey, Vol - 1, Lion Press, Kanpur. 4. Industrial Chemicals by W.L. Faith, D.B. Keyes, and R.L. Clark, Wiley. 5. Encyclopedia of Chemical Technology by Kirk, and Othmer, Wiley.		

Course Name: **Solid Waste Management**
Course Code: **CH-241**
Course Type: **Discipline Elective - I**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- Facilitate understanding of issues and approaches associated with solid waste, hazardous waste and special category waste management.
- Able to access legal requirements and strategies associated with management of municipal, hazardous and special solid waste.

Unit Number	Course Content	Lectures
UNIT-01	**Introduction:** Solid waste management, nuisance potential and extent of solid waste problems, regulatory requirements.	**06L**
UNIT-02	**Characterization and Quantification:** Types, composition, methods of quantification and characterization of wastes.	**06 L**
UNIT-03	**Collection, Storage and Transportation of Wastes:** Types of collection systems and their components, segregation at source, solid waste transport vehicles, solid waste transit points and transport routes, storage and handling of hazardous waste.	**06 L**
UNIT-04	**Municipal Solid Waste Management:** Recycling, recovery of useful components of solid waste and its applications, composting, bio-gasification, waste to energy production. **Hazardous waste Management:** Definition, sources, classification, collection and segregation, chemical and biological treatment of hazardous waste, solidification and stabilization refuse derived fuel, gasification, pyrolysis, incineration, disposal, management of effluent treatment plant sludge.	**08 L**
UNIT-05	**Sanitary landfills:** Site selection and approval, design, development, operation and closer of landfills, management of leachate and landfill gases, environmental monitoring of landfill sites.	**06 L**
UNIT-06	**Special category wastes and their management:** Construction and demolition wastes, biomedical wastes, radioactive waste, E- waste, plastic waste, oil sludge and slurries.	**04 L**

Course Outcomes

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

CO1: Understanding and appreciating the environmental pollution and nuisance potential of municipal solid waste and of special category wastes.

CO2: Awareness of management of MSW and hazardous waste according their characteristics (selection of management technique).

CO3: Acquiring the knowledge of collection and transportation and solid waste route selection and types of waste collection.

CO4: Regulatory requirement applicable to the handling and management of MSW and special category waste.

Books and References

1. Waste management Practices-Municipal, hazardous and industrial by J. Pichtel, CRC Press, 2005.
2. Solid waste engineering by P.A. Vesilind, Thomson, 2008.
3. United Nations Environment Programme (UNEP) Solid Waste Management, 2005.
4. Solid waste management in developing Countries INSDOC by A.D. Blude, and B.B. Sudaresan, 1972.
5. Integrated Solid waste management engineering Principles and management issues by C. Tchobanoglous, S.A. Vigil and H. Theisen, McGraw Hill 1993.
6. Hazardous Waste Management by M. LaGrega, P. Buckingham, J. Evans, and ERM. Inc., McGraw Hill, 2000.

Course Name: **Process Instrumentation** Course Code: **CH- 242** Course Type: **Discipline Elective - I**		
Contact Hours/Week: **3L**		Course Credits: **03**
Course Objectives • To gain knowledge of different process instruments.		
Unit Number	**Course Content**	**Lectures**
UNIT-01	Introduction to Instruments and Their Representation: Application of instrument systems, functional elements of a measurement system, classification of instruments, standards and calibration.	**06 L**
UNIT-02	Temperature Measurement: Temperature Scales, temperature measuring instruments: liquid in glass thermometer, bimetallic thermometer, resistance temperature detectors (RTD), thermocouples, pyrometry.	**06 L**
UNIT-03	Pressure Measurement: Measurement of moderate pressure, high pressure and low pressure (vacuum), calibration and standardization.	**08 L**
UNIT-04	Flow Measurement: Positive displacement meters, variable head meters, variable area meters (rotameters), weirs and notches, pitot tube, electromagnetic flow meter, hot wire anemometer, ultrasonic flow meters, laser Doppler anemometer.	**08 L**
UNIT-05	Miscellaneous Measurements: Liquid level, pH, viscosity, conductivity, humidity, gas composition, and nuclear radiation. Static and Dynamic characteristics of instruments: Errors and uncertainties in performance parameters, propagation of uncertainties in compound quantities, static performance parameters, formulation of system equations, dynamic response, and compensation.	**08 L**

Course Outcomes

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

CO1: Understand about the measurement system.

CO2: Select suitable temperature, pressure, and flow measure instrument.

CO3: Select suitable measure instrument for different parameters.

Books and References

1. Automatic Process Control by D.P. Eckman, Wiley Eastern Ltd., New Delhi.
2. Instrumentation, Measurement and Analysis by B.C. Nakra, and K.K. Chaudhry, 2nd edition, Tata McGraw Hill, New Delhi, 2004.
3. Principles of Industrial Instrumentation by D. Patranabis, Tata McGraw Hill, New Delhi, 1999.
4. Instrument Engineers' Handbook: Process Measurement and Analysis by B.G. Lipták, Vol 1 & 2, CRC Press, 2003.
5. Applied Instrumentation in the Process Industries by W. G. Andrew, et al., Gulf Pub. 1993.
6. Instrumentation in Process Control by E. J. Wightman, Butterworths, 1972.
7. Measurement Systems: Applications and Design by E. Doebelin, 4th edition, McGraw-Hill, 1990.

Course Name: **Industrial Safety and Hazard Management** Course Code: **CH-243** Course Type: **Discipline Elective - I**		
Contact Hours/Week: **3L**		Course Credits: **03**
Course Objectives: • To highlight the importance of industrial safety and measures in order to prevent accidental damage • To explain significant disaster observed in different parts of the world with understanding of the properties of toxic materials • To deal with fire and explosion and concepts to prevent them • To obtain the checklist for process hazards and their safety review		
Unit Number	**Course Content**	**Lectures**
UNIT-01	**Introduction:** Safety program, engineering ethics, concept of loss prevention, accident and loss statistics, acceptable risks, nature of accident process, inherent safety, significant disaster in India, England, Texas, Italy, Florida and Georgia	**07L**
UNIT-02	**Toxicology:** Toxic materials and their properties, toxicants entry route, dose versus response, models for dose and response curves, threshold limit values, national fire protection association diamond	**08L**
UNIT-03	**Industrial Hygiene:** Industrial hygiene anticipation and identification, industrial hygiene evaluation, hygiene control	
UNIT-04	**Fires and Explosion:** Fire triangle, distinction between fires and explosion, definitions, flammability characteristics of liquid and vapors, LOC and inerting, flammability diagram, ignition energy, auto ignition, auto-oxidant, adiabatic compression, ignition source, sprays and mists, ventilation, sprinkler system, types of explosions, explosion-proof equipment and instruments, fire and explosion hazards, causes of fire and preventive methods.	**10L**
UNIT-05	**Hazard identification and Risk Assessment:** Process hazards checklists, hazard survey, hazards and operability studies (HAZOP), safety reviews, other methods, review of probability theory, event tree, fault tree, QRA and LOPA	**10L**
Course Outcomes Upon successful completion of the course, the student will be able to CO1: Develop understanding to select methods on how to prevent fires and explosions CO2: Accomplish understanding on the effect of release of toxic substances CO3: Acquire awareness on the methods of identification of industrial hazards and their preventive measurements CO4: Obtained knowledge on the assessing the risk using fault tree diagram		
Books and References 1. Chemical Process Safety - Fundamentals with Applications by D.A. Crowl, and J.F. Louvar, 3rd edition, Prentice Hall, 2011. 2. Loss Prevention in Process Industries by F.P. Lees, 2nd edition, Butterworth, London, 1996. 3. Safety in Process Plant Design by G.L. Wells, George Godwin Ltd., New York, 1980. 4. Safety Health and Environmental Protection by C.A. Wentz, McGraw Hill, 2001.		

Course Name: **Energy Resource and Utilization**
Course Code: **CH-244**
Course Type: **Discipline Elective - I**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To learn about various renewable and non-renewable energy resources.
- To learn technologies for efficient utilization of non-renewable energy resources
- To understand various renewable energy resources and learn to utilize them efficiently.

Unit Number	Course Content	Lectures
UNIT-01	**Introduction**: Various energy sources, coal, oil, natural gas, nuclear and hydroelectric power. Role of energy in economic development and social transformation. Classification of energy resources: Conventional and nonconventional, renewable-nonrenewable, green energy, clean energy, green footprint, carbon footprint, ecological footprint concepts. **Indian Energy Scene**: Energy resources available in India, urban and rural energy consumption, energy consumption pattern and its variation as a function of time,	**08 L**
UNIT-02	**Types of Power Plants**: Hydroelectric power plants, diesel and gas turbine power plants, thermal**,** solar**,** nuclear and wind power plants.	**07 L**
UNIT-03	**Geothermal energy:** Introduction, estimates of geothermal power. Nature of geothermal fields, geothermal resources, hydrothermal (convective) resources geo pressured resources.	**07 L**
UNIT-04	**Ocean, S Energy:** Introduction, principle of ocean thermal energy conversion, tidal power generation, tidal energy technologies, energy from waves, wave energy conversion, wave energy technologies, advantages and disadvantages.	**08 L**
UNIT-05	**Bio-Energy:** Energy from biomass. Sources of biomass. Different species .Conversion of biomass into fuels. Energy through fermentation. Pyrolysis, gasification and combustion biogas plants.	**05 L**
UNIT-06	**Environmental Effects**: Environmental degradation due to energy production and utilization (thermal, hydro, nuclear), air and water pollution, depletion of ozone layer, global warming, biological damage.	**07 L**

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1: Design efficient energy utilization system.
CO2: Develop new technologies for renewable energy.

Books and References

1. Non-Conventional Energy Sources by G.D. Rai, Khanna publ., New Delhi.
2. Principles of Energy Conversion by A.W. Culp, MGH, New York
3. Solar Energy Principles, Thermal Collection &Storage by S.P. Sukhatme: Tata McGraw Hill Pub., New Delhi.
4. Renewable Energy, power for a sustainable future by Godfrey Boyle, 2004.
5. The Generation of electricity by wind by E.W. Golding.
6. Non-Conventional Energy Resources by B.H. Khan, Tata McGraw Hill Pub., 2009.
7. Fundamentals of Renewable Energy Resources by G.N. Tiwari, and M.K. Ghosal, Narosa Pub.

Course Name: **Heat Transfer Lab**
Course Code: **CH-225**
Course Type: **Discipline Core**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives

- To define the fundamental concepts to students in the area of heat transfer and its applications.
- To recognize the practical significance of various parameters those are involved in different modes of heat transfer.
- To apply the knowledge of heat transfer in an effective manner for different applications.

List of Experiments

1. To determine the heat transfer coefficient of double pipe heat exchanger.
2. To determine the LMTD and overall heat transfer coefficient of shell and tube heat exchanger.
3. To compute the thermal resistance and thermal conductivity of a composite wall.
4. To determine the thermal conductivity in forced convection apparatus.
5. To study the variation of heat transfer coefficient over the surface in natural convection apparatus.
6. To study the drop wise and film wise condensation.
7. To determine the Stefan-Boltzman's constant.
8. To determine the emissivity of a test surface.
9. To study the vertical and horizontal condenser.
10. To determine the efficiency single effect evaporator.
11. To determine the efficiency of plate type heat exchanger.

Course Outcomes

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

CO1: Identify practically different modes of heat transfer viz. conduction, convection and radiation.

CO2: Describe convective heat transfer coefficient, overall heat transfer coefficient and dimensionless numbers.

CO3: Apply principles of heat transfer to various equipments.

CO4: Study various types of heat exchangers and compare their efficiencies.

Course Name: **Thermodynamics Lab** Course Code: **CH-226** Course Type: **Discipline Core**	
Contact Hours/Week: **2P**	Course Credits: **01**

Course Objectives

- To define the fundamental concepts to students in the area of thermodynamics and its applications.
- To recognize the practical significance of various parameters those are involved in different fundamental equations.
- To apply the knowledge of thermodynamics in an effective manner for different applications.

List of Experiments

1. To determine the enthalpy of combustion by using Bomb calorimeter
2. To determine the melting point of liquid and solid substance by using melting point apparatus
3. To determine the vapor pressure of water at high temperature by using vapor pressure measurement apparatus
4. To determine the activity coefficient of a substance by using activity coefficient measurement apparatus
5. To study the vapor-liquid equilibria (VLE) of two phase system
6. To study the calorimetry of solid and liquid in vacuum by using adiabatic calorimeter
7. To Investigate the relationships between pressure and volume (Boyle's law) by using ideal gas law apparatus
8. To measure the dryness factor of steam by using separating & throttling calorimeter
9. To calculate the volumetric efficiency by using single stage air compressor test rig
10. To calculate the volumetric efficiency by using two stage air compressor test rig
11. To determine the thermal conductivity and thermal diffusivity of liquid and solid substances by using thermal conductivity and thermal diffusivity measurement apparatus
12. To study the behavior and expansion processes of a perfect gas by using bench-top apparatus

Course Outcomes

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

CO1: Identify practically melting point of different fluids and substances.

CO2: Describe activity coefficient, ideal gas law and adiabatic conditions.

CO3: Apply thermodynamics concepts towards various equipment and measure thermal conductivity and thermal diffusivity.

CO4: Study various types of calorimeters, air compressors, and their efficiencies.

Course Name: **Chemical Technology Lab** Course Code: **CH-227** Course Type: **Discipline Core**	
Contact Hours/Week: **2P**	Course Credits: **01**

Course Objectives

- To introduce the students with various chemical preparations such as soaps, pigments, resins and dyes.
- To enable the students to analyze and estimate various properties of chemicals and oils.

List of Experiments

1. Preparation and study the properties of soap.
2. Estimation of CaO & silica in Portland cement.
3. Determination of Chlorine content in bleaching powder.
4. Gravimetric analysis of a phosphorus-containing fertilizer.
5. Determination of Saponification value of oil/fat.
6. Determine (semi-quantitatively) concentration of reducing sugarin an unknown sample using Benedict's reagent.
7. Preparation of pigments (barium white, malchite green and chromium oxide green
8. Synthesis of phenol formaldehyde resin (Bakelite).
9. Extraction of oil from any seed material using Soxhlet apparatus.
10. Analysis of flue gas using Orsat Apparatus.
11. Estimation of moisture content of a given sample by Dean and Stark apparatus.
12. Estimation of carbon residue of a given sample using Conradson apparatus.
13. Estimation of cloud and pour point of a given sample.
14. Estimation of flash point, fire point, smoke point of oils.
15. Determination of aniline point of a given oil sample.

N.B.: List of experiments will be finalized by the course instructor at the beginning of the semester.

Course Outcomes

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

CO1: Synthesize various chemicals such as soap, pigments, resign etc.

CO2: Analyze the chemicals for various physico-chemical properties.

CO3: Estimate the concentration of any component in chemicals, oils and flue gasses.

SEMESTER-V

Course Name: **Industrial Safety and Hazard Management**
Course Code: **CH-301**
Course Type: **Institute electives**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives:

- To highlight the importance of industrial safety and measures in order to prevent accidental damage
- To explain significant disaster observed in different parts of the world with understanding of the properties of toxic materials
- To deal with fire and explosion and concepts to prevent them
- To obtain the checklist for process hazards and their safety review

Unit Number	Course Content	Lectures
UNIT-01	**Introduction:** Safety program, engineering ethics, concept of loss prevention, accident and loss statistics, acceptable risks, nature of accident process, inherent safety, significant disaster in India, England, Texas, Italy, Florida and Georgia	**07L**
UNIT-02	**Toxicology:** Toxic materials and their properties, toxicants entry route, dose versus response, models for dose and response curves, threshold limit values, national fire protection association diamond	**08L**
UNIT-03	**Industrial Hygiene:** Industrial hygiene anticipation and identification, industrial hygiene evaluation, hygiene control	
UNIT-04	**Fires and Explosion:** Fire triangle, distinction between fires and explosion, definitions, flammability characteristics of liquid and vapors, LOC and inerting, flammability diagram, ignition energy, auto ignition, auto-oxidant, adiabatic compression, ignition source, sprays and mists, ventilation, sprinkler system, types of explosions, explosion-proof equipment and instruments, fire and explosion hazards, causes of fire and preventive methods.	**10L**
UNIT-05	**Hazard identification and Risk Assessment:** Process hazards checklists, hazard survey, hazards and operability studies (HAZOP), safety reviews, other methods, review of probability theory, event tree, fault tree, QRA and LOPA	**10L**

Course Outcomes

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

CO1: Develop understanding to select methods on how to prevent fires and explosions

CO2: Accomplish understanding on the effect of release of toxic substances

CO3: Acquire awareness on the methods of identification of industrial hazards and their preventive measurements

CO4: Obtained knowledge on the assessing the risk using fault tree diagram

Books and References

1. Chemical Process Safety - Fundamentals with Applications by D.A. Crowl, and J.F. Louvar, 3rd edition, Prentice Hall, 2011.
2. Loss Prevention in Process Industries by F.P. Lees, 2nd edition, Butterworth, London, 1996.
3. Safety in Process Plant Design by G.L. Wells, George Godwin Ltd., New York, 1980.
4. Safety Health and Environmental Protection by C.A. Wentz, McGraw Hill, 2001.

Course Name: **Water and Wastewater Treatment Technologies** Course Code: **CH-302** Course Type: **Institute electives**		
Contact Hours/Week: **3L**		Course Credits: **03**
Course Objectives • To understand the science and technologies of wastewater treatment processes and operations.		
Unit Number	**Course Content**	**Lectures**
UNIT-01	**Wastewater Characteristics and Effluent Standards:** Physical, chemical and biological parameters of water pollution; DO, BOD and BOD kinetics; Nutrients; Effluent standards. **Overview of Wastewater Treatment Technologies:** Preliminary, primary, secondary and tertiary treatment technologies.	**06 L**
UNIT-02	**Preliminary Treatment:** Screens; Grit removal facilities; Effluent sumps and pumps; and Equalization tanks	**06 L**
UNIT-03	**Primary Treatment:** Neutralization and precipitation; Primary and secondary sedimentation tanks; Membrane filtration processes; Roughing filters.	**08 L**
UNIT-04	**Biological Treatment:** Activated sludge process and its modifications including SBR; Trickling filters and RBC units; SAF, FAB and MBBR technologies; UASB reactors and its modifications; Waste stabilization pond systems and its modifications.	**08 L**
UNIT-05	**Advanced Water Treatment Technologies:** Ion-exchange process; Adsorption process; membrane processes (nanofiltration and reverse osmosis); Defluoridation units and household level water purification systems, Advanced oxidation processes; Biological nutrient removal; Filtration and chlorination; Membrane processes for TDS reduction.	**08 L**
Course Outcomes Upon successful completion of the course, the student will be able to CO1: Decide on the scheme of treatment for wastewaters. CO2: Design, analysis, operate and control the routinely used biological wastewater treatment units. CO3: Monitor the wastewater treatment plants and characterize the wastewater samples. CO4: Decide on the facilities and provisions for the handling and management of the water and waste water treatment sludges.		
Books and References 1. Wastewater Engineering – Treatment, Disposal and Reuse by Metcalf, Eddy, G. Tchobanoglous, F.L. Burton, and H.D. Stensel, Tata McGraw Hill, 4th edition, 2002. 2. Industrial Water Pollution Control by WW Jr. Eckenfelder, McGraw Hill, 3rd edition, 2003. 3. Biological Wastewater Treatment, Edited Volume Series, IWA, 2008.		

Course Name: **Energy Resource and Utilization**
Course Code: **CH-303**
Course Type: **Institute Electives**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To learn about various renewable and non-renewable energy resources.
- To learn technologies for efficient utilization of non-renewable energy resources
- To understand various renewable energy resources and learn to utilize them efficiently.

Unit Number	Course Content	Lectures
UNIT-01	**Introduction**: Various energy sources, coal, oil, natural gas, nuclear and hydroelectric power. Role of energy in economic development and social transformation. Classification of energy resources: Conventional and nonconventional, renewable-nonrenewable, green energy, clean energy, green footprint, carbon footprint, ecological footprint concepts. **Indian Energy Scene**: Energy resources available in India, urban and rural energy consumption, energy consumption pattern and its variation as a function of time,	**08 L**
UNIT-02	**Types of Power Plants**: Hydroelectric power plants, diesel and gas turbine power plants, thermal**,** solar**,** nuclear and wind power plants.	**07 L**
UNIT-03	**Geothermal energy:** Introduction, estimates of geothermal power. Nature of geothermal fields, geothermal resources, hydrothermal (convective) resources geo pressured resources.	**07 L**
UNIT-04	**Ocean, S Energy:** Introduction, principle of ocean thermal energy conversion, tidal power generation, tidal energy technologies, energy from waves, wave energy conversion, wave energy technologies, advantages and disadvantages.	**08 L**
UNIT-05	**Bio-Energy:** Energy from biomass. Sources of biomass. Different species .Conversion of biomass into fuels. Energy through fermentation. Pyrolysis, gasification and combustion biogas plants.	**05 L**
UNIT-06	**Environmental Effects**: Environmental degradation due to energy production and utilization (thermal, hydro, nuclear), air and water pollution, depletion of ozone layer, global warming, biological damage.	**07 L**

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1: Design efficient energy utilization system.
CO2: Develop new technologies for renewable energy.

Books and References

1. Non-Conventional Energy Sources by G.D. Rai, Khanna publ., New Delhi.
2. Principles of Energy Conversion by A.W. Culp, MGH, New York
3. Solar Energy Principles, Thermal Collection &Storage by S.P. Sukhatme: Tata McGraw Hill Pub., New Delhi.
4. Renewable Energy, power for a sustainable future by Godfrey Boyle, 2004.
5. The Generation of electricity by wind by E.W. Golding.
6. Non-Conventional Energy Resources by B.H. Khan, Tata McGraw Hill Pub., 2009.
7. Fundamentals of Renewable Energy Resources by G.N. Tiwari, and M.K. Ghosal, Narosa Pub.

Course Name: **Mass Transfer-I** Course Code: **CH-311** Course Type: **Discipline Core**		
Contact Hours/Week: **3L**		Course Credits: **03**
Course Objectives • To impart knowledge about the basics of mass transfer processes. • To introduce the fundamental laws and theories for basic mass transfer processes. • To enable the student to learn about the gas-liquid equilibrium operations.		
Unit Number	**Course Content**	**Lectures**
UNIT-01	**Mass Transfer Operations:** Classification of mass transfer operation, choice of separation methods. Diffusion in Mass Transfer: Steady state molecular diffusion in fluids at rest and in laminar flow, molecular diffusion in gases, molecular diffusion in liquids, diffusivity in liquids and gases, momentum and heat transfer in laminar flow.	**08L**
UNIT-02	**Mass Transfer Coefficient:** Local and overall mass transfer coefficient, heat and mass transfer analogy, eddy diffusivities, Dimensionless numbers and their significance, film theory, penetration theory, surface renewal theories, combination film theory and surface stretch theory.	**07L**
UNIT-03	**Interphase Mass Transfer:** Equilibrium, local two phase mass transfer coefficients, Local overall Mass Transfer coefficients, material balance for co current & counter current processes, and concept of Ideal stage and stage efficiencies, continuous contact equipment.	**07L**
UNIT-04	**Gas Absorption:** Choice of solvent, Estimation of number of ideal stages – Graphical and Analytical methods, Minimum solvent flow rate, Significance of absorption factor, number of transfer units and height of a transfer unit (NTU & HTU) concepts, packed column for absorption, HETP, rate of absorption, height of column based on condition in gas film and liquid film, height based on overall coefficients.	**07L**
UNIT-05	**Humidification and Drying:** Wet and dry bulb hygrometry, Psychometric Chart and its use, cooling towers: classification, construction, operation and calculation, Equilibrium in drying, batch drying and rate of batch drying, time of drying, drying rate calculation, continuous drying equipment.	**07L**
Course Outcomes Upon successful completion of the course, the student will be able to CO1: Familiar with the basic phenomenon, principles and theories of mass transfer CO2: Determine diffusivity and mass transfer coefficient in gases and liquids CO3: Describe the phenomena involving interphase mass transfer in industrial processes CO4: Apply mathematical and design concepts of mass transfer in gas-liquid systems like absorption, humidification, drying processes		
Textbooks and References 1. Separation Process Principles by J. D. Seader and E. J. Henley, 2nd Edition, John Wiley & Sons, 2010. 2. Mass Transfer Operations by R. E. Treybal, 3rd Edition, McGraw Hill, 2012. 3. Transport Processes and Unit Operations by C. J. Geankoplis, 3rd Edition, PHI, 2000. 4. Principles of Unit operations by A S Foust, L A Wenzel, C W Clump, L Naus, L B Anderson, 2nd Edition, John Wiley & Sons, 1980. 5. Unit Operations in Chemical Engineering by McCabe and Smith, 5th Edition, McGraw-Hill, 1993. 6. Chemical Engineering Volume-2 by J. M. Coulson and J. F. Richardson, 5th Edition, Butterworth-Heinemann, 2002. 7. Chemical Engineering Volume-1 by J. M. Coulson and J. F. Richardson, 6th Edition, Butterworth-Heinemann, 1999.		

Course Name: **Chemical Reaction Engineering-I**
Course Code: **CH-312**
Course Type: **Discipline Core**

Contact Hours/Week: **3L + IT** Course Credits: **04**

Course Objectives

- To make the student understand principles and practices followed in chemical industries with respect to reactor design and operation.
- To enable the students to analyse the kinetic data, and to estimate the kinetic parameters.

Unit Number	Course Content	Lectures
UNIT-01	**Reaction kinetics & data analysis:** Kinetics of homogeneous reactions, concentration and temperature dependent term of rate equation, interpretation of batch reactor: constant volume batch reactor, integral and differential method of analysis of data, method of half-life and initial rates, series and parallel reactions, reversible reactions, variable volume batch reactor, temperature and reactions rate	**08 L**
UNIT-02	**Reactor Design**: Ideal batch reactor, CSTR, plug flow reactor, holding and space time, design for single reactions, size comparison (analytical and graphical method, plug flow reactors in series & parallel, mixed reactor in series, recycle and autocatalytic reactions	**08 L**
UNIT-03	**Design for Multiple Reactions:** Reactions in parallel and series in CSTR and plug flow reactor, conversion, yield and selectivity	**06 L**
UNIT-04	**Temperature and Pressure Effect:** General design procedure, optimum temperature progression, adiabatic operation, non-adiabatic operation, semi batch reactors	**06 L**
UNIT-05	**Non-ideal Reactor and Residence Time Distribution:** Fundamentals of non-ideal reactors; measurement and characterization of RTD: C curve, E curve, F curve, mean residence time, different moments; RTD for ideal reactor (batch, CSTR, PFR), tanks in series model, dispersion model	**08 L**

Course Outcomes

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

CO1: Derive the rate law for elementary and non-elementary reactions.
CO2: Determine the kinetics of chemical reaction from the data using integral, differential method of analysis.
CO3: Design of reactors for conducting the homogeneous reactions under isothermal conditions.
CO4: Compare the performance of ideal reactors.
CO5: Analyse the performance of non-ideal reactors using various models.

Textbooks and References

1. Elements of Chemical Reaction Engineering by H.S. Fogler, PHI, 2010.
2. Chemical Reaction Engineering by O. Levenspiel, Wiley, 2007.
3. Chemical Reactor Analysis and Design by G.F. Froment, K.B. Bischoff and J.D. Wilde, Wiley, 2011.
4. Chemical Engineering Kinetics by J.M. Smith, McGraw-Hill, 1970.
5. Introduction to Chemical Engineering Kinetics and Reactor Design by C.G. Hill and T.W. Root, Wiley, 2014.

Course Name: **Process Dynamics and Control**
Course Code: **CH-313**
Course Type: **Discipline Core**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To analyze the system behavior for the design of various control schemes, and to gain knowledge of different process instruments.

Unit Number	Course Content	Lectures
UNIT-01	**Introduction:** General Principles of process control, Time domain, Laplace domain and frequency domain dynamics and control.	**04L**
UNIT-02	**Linear Open-loop Systems:** Laplace domain analysis of first and second orders systems, Linearization, Response to step, pulse, impulse and ramp inputs, Physical examples of first and second order systems such as thermocouple, level tank, U-tube manometer, etc., Interacting and non-interacting systems, Distributed and lumped parameter systems, Dead time.	**8L**
UNIT-03	**Linear Closed-loop Systems:** Controllers and final control elements, Different types of control valves and their characteristics, Development of block diagram, Transient response of simple control systems, Stability in Laplace domain, root locus diagram.	**08L**
UNIT-04	**Frequency Response:** Frequency domain analysis, Control system design by frequency response, Bode stability criterion, Nyquist stability criteria, design of controllers, Different methods of tuning of controllers.	**08L**
UNIT-05	**Process Applications:** Introduction to advanced control techniques as feed forward, feedback, cascade, ratio, etc., Application to equipment such as distillation-columns, reactors, etc.	**08L**

Course Outcomes

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

CO1: Set up a model, analyse and solve the first and second order system for its dynamic behaviour.
CO2: Evaluate the process stability in Laplace domain.
CO3: Design control system using frequency response analysis
CO4: Identify advanced control techniques for chemical process.

Textbooks and References

1. Process Systems Analysis and Control by D.R. Coughanowr and S.E. LeBlanc, McGraw Hill, 2009.
2. Automatic Process Control by D.P. Eckman, Wiley Eastern Ltd., New Delhi.
3. Chemical Process Control: An Introduction to Theory and Practice by G. Stephanopoulous, Prentice Hall of India, 1984.
4. Process Control by P. Harriott, Tata McGraw Hill, 1972.

Course Name: **Thermodynamics of Phase and Chemical Equilibria**
Course Code: **CH-351**
Course Type: **Discipline Elective - II**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives:

- To impart knowledge about the basic concepts of chemical engineering thermodynamics.
- To introduce the fundamental concepts relevant to different chemical process.
- To enable the students to understand the factors that causes the thermodynamic challenges in different chemical industries.

Unit Number	Course Content	Lectures
UNIT-01	**Review of fundamental principles:** Review of thermodynamic laws, thermodynamic potentials, thermodynamic stability, and thermodynamic properties of pure substances	**05 L**
UNIT-02	**Thermodynamic properties of mixtures:** Ideal gas mixtures, ideal or Lewis mixtures chemical potential and fugacity, partial molar properties, calculation of fugacity and fugacity coefficients, excess properties, concept of activity coefficient, correlative activity coefficient models	**09 L**
UNIT-03	**Phase equilibria:** Fundamental VLE equation,VLE at low, moderate and high pressures, azeotropic data, multi-component VLE, thermodynamic consistency test of VLE data, liquid-liquid equilibria, chemical reaction equilibria	**08 L**
UNIT-04	**Intermolecular forces:** Interactions between molecules, electrostatics and dipoles, potential energy functions, molecular dynamics simulations	**06 L**
UNIT-05	**Statistical thermodynamics:** Quantum mechanical aspects, thermodynamic probability and entropy, Boltzmann's distribution law, partition function, thermodynamic properties in terms of partition functions, partition functions of polyatomic molecules	**07 L**

Course Outcomes

Upon successful completion of the course, the students will be able to;
CO1: Identify and understand the peculiar thermodynamic properties.
CO2: Describe the different thermodynamic aspects based on fundamental concepts.
CO3: Apply principle of thermodynamics laws to determine the different equilibrium states.
CO4: Assess the importance of applications of thermodynamic laws in related fields

Books and References

1. Molecular Thermodynamics of Fluid Phase Equilibria by J. M. Prausnitz, R. N. Lichtenthaler, E. Gomes-deAzevedo, Prentice Hall.
2. Chemical, Biochemical and Engineering Thermodynamics by S.I. Sandler, John Wiley & Sons.
3. Chemical Engineering Thermodynamics by Y. V. C. Rao, Universities Press.
4. Introduction to Chemical Engineering Thermodynamics by J. M. Smith, H. C. Van-Ness, M. M. Abbott, McGraw Hill.
5. Engineering and Chemical Thermodynamics by M. D. Koretsky, Wiley.

Course Name: **Fuel Cells and Hydrogen Energy**		
Course Code: **CH-352**		
Course Type: **Discipline Elective - II**		
Contact Hours/Week: **3L**		Course Credits: **03**

Course Objectives

- To learn the fundamental knowledge about various fuel cell technologies.
- To model fuel cells and its' characterization techniques.
- To provide comprehensive and logical knowledge of hydrogen production, storage and utilization.

Unit Number	Course Content	Lectures
UNIT-01	**Fuel Cells and its' Characterization:** History, working principle of fuel cells, fuel cell thermodynamics, fuel cell electrochemistry - Nernst equation, electrochemical kinetics, Butler-Volmer equation, performance evaluation of fuel cells, types of fuel cells: AFC, PAFC, SOFC, MCFC, DMFC, relative merits and demerits, in-situ and ex-situ characterization techniques, I-V curve, frequency response analyses; Fuel cell system integration.	**07L**
UNIT-02	**Application of Fuel Cells:** Fuel Cell usage for domestic power systems, environmental analysis, large scale power generation, automobile. Future trends in fuel cells, portable fuel cells, laptops, mobiles, submarines.	**06L**
UNIT-03	**Hydrogen Energy Systems:** Properties of hydrogen as a fuel, hydrogen pathways, current uses, infrastructure requirement for hydrogen production, storage, dispensing and utilization, and hydrogen production plants.	**07L**
UNIT-04	**Hydrogen Production Processes:** Thermal-steam reformation, thermo chemical water splitting, gasification-pyrolysis, nuclear thermal catalytic and partial oxidation methods. Electrochemical-Electrolysis, photo electro chemical method.	**08L**
UNIT-05	**Hydrogen Storage and Safety:** Physical and chemical properties, general storage methods, compressed storage-composite cylinders, metal hydride storage, carbon-based materials for hydrogen storage. Hydrogen safety aspects, backfire, pre-ignition, hydrogen emission, NOx control techniques and strategies, hydrogen powered vehicles.	**05L**

Course Outcomes

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

CO1: Evaluate the performance of fuel cells under different operating conditions.
CO2: Select and defend appropriate fuel cell technology for a given application.
CO3: Design and develop suitable hydrogen storage system to be used along with fuel cell system.
CO4: Minimize environmental hazards associated with the use of hydrogen storage and fuel cell technology.

Textbooks and References

1. Electrochemical Methods by A.J. Bard, and L.R. Faulkner, 2nd edition, John Wiley & Sons, 2001.
2. Fuel Cell Fundamentals by O'Hayre, S.W. Cha, W. Colella, and F.B. Prinz, Wiley, 2005.
3. Principles of Fuel Cells by X. Li, Taylor & Francis, 2005.
4. Fuel Cell Systems Explained by J. Larminie, and A. Dicks, 2nd edition, John Wiley & Sons, 2003.
5. Fuel Cells: From Fundamentals to Applications by S. Srinivasan, Springer, 2006.

Course Name: **Food Science and Engineering**
Course Code: **CH-353**
Course Type: **Discipline Elective - II**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart knowledge to the students about food process engineering
- To teach about food preservation and packaging.
- To understand the hazards and safety in food industries.

Unit Number	Course Content	Lectures
UNIT-01	**Introduction:** General aspects of food industry, composition of foods, quality and nutritive aspects, characteristic features of processed and natural food, mass and energy balance in food processing operation.	**06L**
UNIT-02	**Food Rheology:** Characteristics of non-Newtonian fluids, time-independent and time dependent non-Newtonian fluids, linear viscoelastic fluids.	**06L**
UNIT-03	**Thermal Processing:** Canning/retort processing – process design and equipment's. Equipment design aspects of pasteurizer, sterilizers, evaporators and concentrators, dryers and their design parameters – tray dryer, spray dryer, fluidized bed dryer.	**07L**
UNIT-04	**Food Preservation:** Microbial survivor curves, thermal death of microorganisms and D, Z and F value calculation, spoilage probability, food preservation by dehydration, irradiation, Food preservation by adding preservatives. Food production,	**06L**
UNIT-05	**Packaging and Storage:** Process design aspects for liquid foods such as milk and juices. Concentration with thermal and membranes processes. Food packaging and product shelf life, modified atmosphere and controlled atmosphere storage, aseptic packaging, freezing and thawing calculations.	**07L**
UNIT-06	**Food Laws:** Legislation, safety and quality control.	**04 L**

Course Outcomes

Upon successful completion of the course, the student will be able to
CO1: Understand rheological properties of foods.
CO2: Identify and evaluate various design parameters for thermal equipment for food.
CO3: Quantify thermal death of micro-organism and calculate spoilage probability
CO4: Evaluate effect of food processing and packaging/storage on food quality
CO5: Analyze food related hazards and HACCP method.

Textbooks and References

1. Food Science by N.N. Potter, and H. Joseph, CBS Publisher, 2005.
2. Fundamentals of Food Process Engineering by T. Romeo, CBS Publisher, 2007.
3. Food Processing by V.H. Potty, and M.J. Mulky, Oxford and IBH, 1993.
4. Food Process Engineering by D.R. Heldman, and R.P. Singh, Chapman and Hall, 1984.
5. Food Microbiology by W.C. Frazier, Tata McGraw Hill, 2007.

Course Name: **Fluidization Technology** Course Code: **CH-354** Course Type: **Discipline Elective - II**		
Contact Hours/Week: **3L**		Course Credits: **03**
Course Objectives: • To have better understanding of fluidization phenomena to develop generic fluidized bed reactor models • To investigate new diagnostic methods and analysis techniques to enable more reliable design and operation of industrial-scale fluidized bed reactors		
Unit Number	**Course Content**	**Contact Hours**
UNIT-01	Introduction to fluidization, types of fluidization, Gross behaviour of fluidized beds, Minimum fluidizing velocity and pressure drops, Distributor design, Voidage, transport disengaging height.	**08L**
UNIT-02	Bubbles in dense beds, Davidson Model, stream of bubbles, bubbling bed models, Emulsion phase, Turn-over rate of solids, residence time distribution diffusion model of solids movement, interchange coefficient into and out of wake.	**07L**
UNIT-03	Diffusion model for gas flow two region models, evaluation of interchange coefficients. Mass and heat transfer between fluids and solid from bubbling bed model Catalytic conversion from bubbling bed model contacting efficiency application to successive reactions Theories and bed-wall heat transfer comparison of theories.	**07L**
UNIT-04	Entrainment and elutrition, application of entrainment model Residence time distribution and size distribution of solids in fluidized beds, particles of changing size Circulation rates of solids, flow of high and low bulk density mixtures.	**08L**
UNIT-05	Design for catalytic reactors Design for noncatalytic gas-solid reactors.	**06L**
Course Outcomes Upon successful completion of the course, the student will be able to CO1: Understand basics of fluidization and its industrial application. CO2: Explain the various fluidization regimes and describe the staging of fluidized beds. CO3: Develop generic fluidized bed reactor models		
Books and References: 1. Fluidization Engineering, 2nd ed., D. Kunii and O. Levenspiel, Butterworth-Heinemann, London, 1999. 2. J.F. Davidson and D. Harrison, *Fluidization*, , Academic Press, , 1971 3. C. K. Gupta, D. Sathiyamoorth, *Fluid Bed Technology in Materials Processing*,, CRC Press, 1st edition, 1998 4. F.A. Zenz and D.F. Othmer, *Fludization and Fluid Particles Systems*, Reinhold Publishing , 1960		

Course Name: **Chemical Reaction Engineering Lab**
Course Code: **CH-314**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives

- To understand the basics of Reaction Engineering and various types of reactors.
- To provide hands-on experience about carrying out reaction in different types of reactors to verify theoretical principles.
- To learn about the estimation of reaction kinetic parameters and RTD practically.

List of Experiments

1. Study of a non-catalytic homogeneous reaction in a CSTR under isothermal conditions.
2. Study of a non-catalytic homogeneous reaction in a PFR under isothermal conditions.
3. Study of a non-catalytic homogeneous reaction in a PBR under isothermal conditions.
4. Study of Residence time distribution (RTD) in a PFR.
5. Study of Residence time distribution (RTD) in a PBR.
6. Study of Residence time distribution (RTD) in CSTR.
7. Study of a non-catalytic homogeneous reaction in a Batch Reactor under isothermal conditions.
8. Study of hydrodynamics of trickle bed reactor.
9. Study of reaction kinetics in spinning basket reactor.
10. Study of reaction kinetics in a adiabatic batch reactor.
11. Study of reaction kinetics in cascade continuous stirred tank reactor.
12. Study of reaction kinetics in Semi-batch reactor under isothermal condition.

Course Outcomes

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

CO1: Learn how to experimentally verify various theoretical principles.

CO2: Estimate kinetic parameters for various reactors.

CO3: Identify the ideal or non-ideal behavior of the reactor by RTD study.

CO3: Develop experimental skill.

Course Name: **Process Dynamics and Control Lab** Course Code: **CH-315**	
Contact Hours/Week: **2P**	Course Credits: **01**
Course Objectives • To learn about basics of control • To learn about pneumatic valve characteristics • To study level, temperature and flow control	
List of Experiments 1. The response of thermometer 2. Dead weight pressure gauge 3. Control valve characteristics 4. Interacting and non-interacting systems 5. Temperature controller 6. Flow controller 7. Study of PI and IP converter 8. Level control trainer 9. Cascade control trainer 10. Pressure controller 11. Ratio controller	
Course Outcomes Upon successful completion of the course, the student will be able to CO1: Find parameters of two tank system and verify PI-IP conversion CO2: Control level, flow and temperature using control system CO3: Draw valve characteristic curve	

SEMESTER-VI

Course Name: **Mass Transfer-II** Course Code: **CH-321** Course Type: **Discipline Core**		
Contact Hours/Week: **3L+1T**		Course Credits: **04**

Course Objectives

- To impart knowledge about the various mass transfer equilibrium.
- To introduce the industrially important mass transfer processes such as distillation, extraction, leaching etc.
- To enable the student to solve design problems related to mass transfer equipment.

Unit Number	Course Content	Lectures
UNIT-01	**Distillation:** Vapor-liquid equilibria, Raoult's Law and Dalton's law, partial vaporization and partial condensation, relative volatility, differential distillation, flash distillation, steam distillation, continuous rectification: binary system; McCabe–Thiele and Ponchon Savarit methods, Fenske, Underwood and Gilliland equations, total reflux, minimum and optimum reflux ratios, multiple feeds and side streams	**11 L**
UNIT-02	**Liquid–Liquid Extraction:** Ternary phase diagrams and solvent selection, single stage & multistage cross current, co-current and counter current extraction operation for immiscible and miscible solvents, batch and continuous contact extractors	**07 L**
UNIT-03	**Leaching:** Solid-liquid equilibria, single stage & multistage cross current, co-current and countercurrent leaching operations, supercritical fluid extraction, equipment for leaching	**06 L**
UNIT-04	**Adsorption:** Introduction and the nature of adsorbent, adsorption equilibria, Langmuir, Freundlich, BET and Gibbs isotherms, potential theory, adsorption equipment, pressure and temperature swing adsorption, ion-exchange equilibria	**06 L**
UNIT-05	**Crystallization:** Formation of nuclei, nuclei growth and properties of crystals, effect of impurities on crystals formation, effect of temperature on solubility, caking of crystals, yield of crystals, crystallizers	**06 L**

Course Outcomes

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

CO1: Familiar with the mass transfer equilibrium and mass transfer operations.

CO2: Determine the No. of plates, height of column using analytical and graphical techniques in distillation and, extraction and leaching operations.

CO3: Selection of solvent for extraction and leaching operations.

CO4: Understand the mechanisms of adsorption and crystallization.

Textbooks and References

1. R.E. Treybal, Mass Transfer Operations, McGraw Hill, 1980.
2. B.K. Dutta, Principles of Mass Transfer and Separation Processes, Prentice Hall of India, 2006.
3. C.J. Geankopolis, Transport Processes and Separation Process Principles, Prentice Hall of India, Eastern Economy Edition, 2004.
4. J.M. Coulson, and J.F. Richardson, Chemical Engineering, McGraw Hill, Vol. – 2 & 5, 1999.
5. W. McCabe, J. Smith, and P. Harriott, Unit Operations of Chemical Engineering, McGraw Hill, 2017.

Course Name: **Chemical Reaction Engineering-II**
Course Code: **CH-322**
Course Type: **Discipline Core**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To provide the students with principles and kinetic tools useful in analyzing the rates of chemical reactions for heterogeneous systems.
- To enable the students to do the design of heterogeneous reactor systems.

Unit Number	Course Content	Lectures
UNIT-01	**Catalysis:** Theories of heterogeneous catalysis, classification of catalysts, catalyst preparation, promoter and inhibitors, catalysts deactivation, steps in a catalytic reaction, synthesizing a rate law, mechanism and rate limiting step, heterogeneous data analysis for reactor design, reactor design.	**08L**
UNIT-02	**Catalysts preparation and properties:** Classification of solid catalysts, preparation methods, unit operations in catalyst preparation, determination of surface area, void volume and solid density, pore volume distribution.	**06L**
UNIT-03	**Internal Diffusion:** Quantitative aspects of pore diffusion-controlled reactions (single cylindrical pore), effective diffusivity, mole balance for the elementary slice of catalyst pore, Thiele Modulus and internal effectiveness factor, overall effectiveness factor.	**06L**
UNIT-04	**External Diffusion:** Concept of external diffusion control, external resistance to mass transfer, mass transfer to a single particle, mass transfer limited reaction in a packed bed, shrinking core model (catalyst regeneration).	**06L**
UNIT-05	**Introduction to Fluid Reactions:** Kinetic regimes for mass transfer and reaction, film conversion parameter, clues to the kinetic regime from solubility data, clues to the kinetic regime from equipment, applications to design.	**05L**
UNIT-06	**Fluid-Particle Reactions:** Selection of model, unreacted core model for spherical particles, diffusion through gas film control and diffusion through ash layer control, chemical reaction control, design.	**05L**

Course Outcomes

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

CO1: Derive the rate law for a catalytic reaction using the kinetic data.
CO2: Determine the properties and effectiveness factor of catalyst.
CO3: Understand the effect of velocity, particle size and fluid properties on rate of reactions controlled by mass transfer.
CO4: Design fixed bed reactors involving chemical reactions with mass transfer.
CO5: Analyze the fluid particle reactions using the models.

Textbooks and References

1. Elements of Chemical Reaction Engineering by H.S. Fogler, PHI, 2010.
2. Chemical Reaction Engineering by O. Levenspiel, Wiley, 2007.
3. Chemical Reactor Analysis and Design by G.F. Froment, K.B. Bischoff and J.D. Wilde, Wiley, 2011.
4. Chemical Engineering Kinetics by J.M. Smith, McGraw-Hill, 1970.
5. Introduction to Chemical Engineering Kinetics and Reactor Design by C.G. Hill and T.W. Root, Wiley, 2014.

Course Name: **Transport Phenomena**
Course Code: **CH-323**
Course Type: **Discipline Core**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To study three closely related transport processes fluid dynamics, heat transfer, and mass transfer in chemical engineering together.
- To leverage various advanced solution methods, each solution beginning with differential forms of the equations of change.
- To train the student to create chemical engineering knowledge using the transport phenomena approach with special focus on combined transport problems.

Unit Number	Course Content	Lectures
UNIT-01	**Momentum Transport:** Viscosity and the mechanism of momentum transport, Newton's law of viscosity, non- Newtonian fluids, pressure and temperature dependence of viscosity, theory of viscosity of gases at low density, theory of viscosity of liquids. Velocity Distributions in Laminar Flow: Shell momentum balances: boundary conditions, flow of a falling film, flow through a circular tube, flow through an annulus, adjacent flow of two immiscible fluids.	**07L**
UNIT-02	**Energy Transport:** To equation of continuity, the equation of motion, the equation of mechanical energy. Thermal Conductivity and the Mechanism of Energy Transport: Fourier's Law of heat conduction, temperature and pressure dependence of thermal conductivity in gases and liquids, theory of thermal conductivity of gases at low density, theory of thermal conductivity of liquids, thermal conductivity of solids. Temperature Distributions in solids and in Laminar Flow: Shell energy balances; boundary conditions, heat conduction with an electrical heat source, heat conduction with a chemical heat source, heat conduction through composite walls: Addition of Resistance, Forced Convection, Free Convection.	**08L**
UNIT-03	**The Equations of change for Non isothermal systems:** The equations of energy, the energy equation in curvilinear coordinates, the equations of motion for forced and free convection in non-isothermal flow, summary of the equations of change, use of equation of change to set up steady-state heat transfer problems.	**06L**
UNIT-04	**Diffusivity and the Mechanism of Mass Transport**: Definition of concentrations, velocities and mass fluxes, fick's law of diffusion, theory of ordinary diffusion in gases at low density, theory of ordinary diffusion in liquids.	**06L**
UNIT-05	**Concentration Distributions in Solid and in Laminar Flow:** Shell mass balances: boundary conditions, diffusion through a stagnant gas film, diffusion with heterogeneous chemical reaction, diffusion with homogeneous chemical reaction, diffusion into a falling liquid film l forced – convection mass transfer, analogies between heat, mass and momentum transfers.	**07L**

Course Outcomes

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

CO1: Understand the general form and solution strategy for transport phenomena problem

CO2: Develop an understanding through examples of how the general form is converted to a specific solutions

CO3: Review and recall how the basic vector and matrix operators are used in defining Transport Phenomena problems

CO4: Understand the concept of diffusive transport of conserved quantities: Fick's Law, Fourier's Law, Newton's Law

CO5: Become familiar with the general expression for diffusive flux of a conserved quantity

Textbooks and References

1. Transport Phenomena by R. B. Bird, W. E. Stewart and E. E. Lightfoot, 2nd Edition, John Wiley & Sons, 2007.
2. Analysis of Transport Phenomena by W. M. Deen, 2nd Edition, Oxford University Press, 2013.

Course Name:	**Advanced Process Control**
Course Code:	**CH-341**
Course Type:	**Discipline Elective - III**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives:

- To impart knowledge about the advanced control methods used in industries and research.
- To understand the stability of multi-variable control system.
- To enable the students to understand the various factors that affects the control system.

Unit Number	Course Content	Lectures
UNIT-01	**Review of Systems:** Review of first and higher order systems, closed and open loop response. Response to step, impulse and sinusoidal disturbances. Transient response.	**08L**
UNIT-02	**Block diagrams; Feed Back Control:** stability using root-locus, and frequency response method, time-integral performance criteria of controllers and tuning methods.	**08L**
UNIT-03	**Advanced Control Systems:** Control of systems with inverse response, dead time compensator, cascade control, selective control, split-range control, feed forward and ratio control, internal model, adaptive and inferential control.	**08L**
UNIT-04	**Multivariable Control Systems:** Alternative control configurations, interaction and decoupling of loops, relative gain-array method, control for complete plants, State Space Methods: State variables, description of physical systems, transition and transfer function matrices, use in multivariable control for interacting systems;	**14L**
UNIT-05	**Digital Control Systems:** Review of Z transform, elements of digital control loop, sampling and reconstruction of signals, conversion of continuous to discrete-time models, discrete time response and stability, design of controllers, control algorithms.	**10L**

Course Outcomes

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

CO1: Perform stability analysis and controller tuning

CO2: Select and design advanced controllers that need to be used for specific problems

CO3: Design controllers for interacting multivariable systems

CO4: Understand the dynamic behavior of discrete time processes and design discrete

Books and References

1. Process System Analysis and Control by D.R. Coughanowr, S. LeBlanc, McGraw Hill, 2009.
2. Chemical Process Control – An Introduction to Theory and Practice by G. Stephanopoulos, Prentice-Hall of India, 1984.
3. Process Dynamics Control by D.E. Seborg, T.F. Edgar, D.A. Mellichamp, John Wiley & Sons.
4. Process Control: Modeling, Design and Simulation by B.W. Bequette, Prentice Hall of India.
5. Process Dynamics Modeling and Control by B.A. Ogunnaike, W.H. Ray, Oxford University Press.

Course Name: **Soft Computing Methods in Chemical Engineering**
Course Code: **CH-342**
Course Type: **Discipline Elective - III**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives:

- To apply soft computing methods in various chemical process.

Unit Number	Course Content	Lectures
UNIT-01	**Artificial intelligence (AI) in Chemical Engineering**: Introduction to AI programming, introduction to prolog, introduction to AI principles, prolog, expert system for separation synthesis	**07L**
UNIT-02	**Introduction to artificial neural networks (ANN) in Chemical Engineering**: fundamentals of neural networks, application of ANN to process control, fault diagnosis, process modeling, process forecasting, limitations of ANN	**07L**
UNIT-03	**Knowledge based applications in Chemical Engineering:** process fault diagnosis, process control, process planning and operation, product design and development, process modeling and simulation	**07L**
UNIT-04	**Elementary Concept of Statistics:** significance tests, Linear regression, hypothesis testing, analysis of variance	**07L**
UNIT-05	**Design of Experiments:** Nonlinear parameter estimation, Model building and model discrimination.	**08L**

Course Outcomes

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

CO1: Understand the use of Artificial Intelligence in chemical engineering and develop the idea on knowledge based applications in chemical engineering.

CO2: Ability to solve engineering problems using soft computational techniques.

CO3: Ability to convert problem solving strategies to procedural algorithms and to write program structures

CO4: Identify advanced control techniques for chemical process.

Books and References

1. Artificial Intelligence in Chemical Engineering by T.E. Quantrille and Y.A. Liu, Academic Press, 1991.
2. Computational Methods for Process Simulation by W. F. Ramirez, Butterworth Heinemann, 1998.
3. Design and Analysis of Experiments by D. C. Montgomery, John Wiley and Sons, 1984.
4. Applied Regression Analysis by N.R. Draper and H. Smith, Wiley, 1998.
5. Experimental Methods for Engineers by J. P. Holman, 7th edition, McGraw-Hill, Singapore, 2001.
6. Process Analysis by Statistical Analysis by D. M. Himmelblau, John Wiley and Sons, 1970.
7. Mathematical Modelling in Chemical Engineering by R.G. Franks, Wiley Publications, 1967.

Course Name: **Fertilizer Technology**
Course Code: **CH-343**
Course Type: **Discipline Elective - III**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives:

- To impart knowledge about N-P-K fertilizers and calculation of N-P-K values in complex fertilizers.
- To introduce the fundamentals of fertilizer preparation technology and respective flow diagrams.
- To enable the student to understand various problems occur in fertilizer production and dealing with these problems as a chemical engineer.

Unit Number	Course Content	Lectures
UNIT-01	**Introduction:** Elements required for plants growth, Macro elements and Micro elements, Classification of fertilizers, Compound, Complex & bulk blended fertilizers. N-P-K values & calculations.	**10L**
UNIT-02	**Nitrogenous Fertilizers**: Manufacturing Processes for Ammonia, Effects of various factors on the process. Manufacture of Mono and Di-ammonium sulphate, ammonium chloride, Ammonium phosphate, Ammonium nitrate, nitric acid Urea etc. Economics & other strategies, Material of construction and corrosion problem.	**12L**
UNIT-03	**Phosphatic Fertilizers:** Calculation of percentage tricalcium phosphate of lime in phosphatic rock. Manufacture of triple super phosphate & single super phosphate.	**10L**
UNIT-04	Nitrophosphate, Sodium phosphate, phosphoric acid & other phosphatic fertilizers.	
UNIT-05	**Potash Fertilizers:** Manufacture of potash fertilizers like potassium sulphate, potassium chloride, potassium nitrite liquid fertilizers, etc. Controlled release fertilizers.	**08L**

Course Outcomes

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

CO1: Identification and calculation of complex fertilizers.

CO2: Describe and analyze the production methods of nitrogenous, phosphatic and potash fertilizers using simple process flow diagram and complex process and instrumentation diagram.

CO3: Apply Principles of chemical engineering in fertilizer production like mass and energy balances.

CO4: Asses the problems in production process and then addressing problems by using chemical engineering basics.

Books and References:

1. Outlines of Chemical Technology by C.E. Dryden, 2nd Edition, East –West Press, 1973.
2. Shreve’s Chemical Process Industries by G.T. Austin, 5th Edition, McGraw Hill, 1986.
3. Chemical Engineering Education Development Centre– Chemical Technology I, II, III, IV, Manual of Chemical Technology, Indian Institute of Technology, Madras.
4. A text book of Chemical Technology by S.D. Shukla and G.N. Pandey, Vikas Publishing House.
5. Hand book on Fertilizers, Fertilizer Association of India, New Delhi

Course Name:	**Reservoir Engineering**
Course Code:	**CH-344**
Course Type:	**Discipline Elective - III**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives:

- To understand a petroleum reservoir and study the basic properties of rock and reservoir fluid.
- To enable the students to identify the concept of PVT analysis and material balance of hydrocarbon reservoir to estimate the oil in place.
- To visualize the fluid flow, understand the drive mechanism and various methods for oil and gas recovery.

Unit Number	Course Content	Lectures
UNIT-01	**Fundamentals of Reservoir Engineering:** Origin and composition of petroleum, petroleum geology, calculation of hydrocarbon volumes, fluid pressure regime, oil recovery: recovery factor, volume gas reservoir engineering, application of the real gas equation of state, gas material balance: recovery factor, hydrocarbon phase behavior, PVT analysis.	**06 L**
UNIT-02	**Reservoir Rock and Fluid Properties**: Porosity, saturation, wettability, surface and interfacial tension, capillary pressure, permeability, rock compressibility, net pay thickness, reservoir heterogeneity, areal heterogeneity, two and three phase relative permeability, drainage and imbibition process	**06 L**
UNIT-03	**Material Balance in Oil and Gas Reservoirs:** General material balance for hydrocarbon reservoir, material balance expressed as linear equation, reservoir drive mechanisms, solution gas drive, gas cap drive, natural water drive, compact drive and combination drive	**08 L**
UNIT-04	**Flow in Porous Media:** Types of fluid, flow regime, reservoir geometry, number of flowing fluid in the reservoir: Darcy's Law, steady and unsteady state flow, skin factor, radial steady state flow: well simulation, two phase flow: effective and relative permeability, derivation of the basic radial differential equation, conditions of solutions, theory of well testing	**08 L**
UNIT-05	**Enhance Oil Recovery Techniques:** Basic principles and mechanism of EOR, IOR and EOR, selection criteria for EOR, microscopic and macroscopic displacement efficiency, mobility ratio, water flooding, chemical flooding, microbial and thermal enhanced oil recovery	**08 L**

Course Outcomes

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

CO1: To understand reservoir properties and their impact on oil recovery.

CO2: To estimate the hydrocarbon by oil and gas material balance equations.

CO3: Acquire the knowledge on multiphase flow in porous media.

CO4: Understand different available enhanced oil recovery schemes.

Books and References

1. Fundamentals of Reservoir Engineering by L.P. Dake, Elsevier, 1983.
2. Enhanced Oil Recovery by D.W. Green, and G.P. Willhite, SPE Textbook Series, 1998.
3. Applied Petroleum Reservoir Engineering by R.E. Terry, M. Hawkins and B.C. Craft, Prentice Hall, 1991.
4. Reservoir Engineering Handbook by T. Ahmed, 3rd edition, Gulf Professional Publishing2006.

Course Name: **Biochemical Engineering**
Course Code: **CH-345**
Course Type: **Discipline Elective - III**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart the basic importance and need for biochemical engineering in industry.
- To develop understanding about enzyme and cell kinetics.
- To enable the students to understand the various aspects of bioreactor design.

Unit Number	Course Content	Lectures
UNIT-01	**Introduction:** Types of Microorganisms: Structure and function of microbial cells, Fundamentals of microbial growth, batch and continuous culture, Sterilization methods, Isolation and purification of enzymes from cells, Downstream processing and product recovery in bioprocesses, Assay of enzymes, cell growth measurement.	**08L**
UNIT-02	**Enzyme Technology and Kinetics:** Applied enzyme catalysis, Immobilization of enzymes, Kinetics of enzyme catalytic reactions involving isolated enzymes, Enzyme inhibition, effect of pH and temperature on enzyme activity	**07L**
UNIT-03	**Enzymatic Reactions and Reactors:** Reactor Design and Analysis for soluble enzyme systems, Cofactor regeneration, Membrane reactor, Effect of mass transfer in immobilized enzyme particle systems, Reactors for immobilized enzyme systems.	**07L**
UNIT-04	**Bio Reactors Design and Transport Processes:** Introduction to Bioreactor design: Batch and Continuously Stirred aerated tank bioreactors, Mixing power correlation, Determination of volumetric mass transfer rate of oxygen from air bubbles and effect of mechanical mixing and aeration on oxygen transfer rate, heat transfer and power consumption, Multiphase bioreactors and their applications.	**08L**
UNIT-05	**Applications:** Applications of enzymes in industry and medicine, Carbohydrates, starch conversion and cellulose conversion, Biological wastewater treatment.	**06L**

Course Outcomes

Upon successful completion of the course, the students will be able to;
CO1: Gain general knowledge about cell cultivation and enzymatic processes, and downstream processing.
CO2: Get a working knowledge of different immobilization methods and enzyme inhibitions.
CO3: Understand enzyme kinetics and cell growth kinetics.
CO4: Design various bioreactors.

Books and References

1. Biochemical Engineering Fundamentals by J.E. Bailey, D.F. Olis, 2nd Ed., McGraw-Hill, 1987.
2. Biochemical Engineering by M. Doble, S.N. Gummadi, Prentice Hall, 2007.
3. Bioprocess Engineering by M.L Schuler, F. Kargi, 2nd Ed., Prentice Hall, 2002.
4. Chemical Engineering Vol -3 by J.M. Coulson, R.E. Richardson, 3rd Ed., Elsevier, 2014.
5. Biotechnology: The Biological Principles by M.D. Trevan, S. Boffey, K.H. Goulding and P. Stanbury, Tata McGraw Hill Publishing Co., New Delhi, 1987.

Course Name: **Colloid and Interface Science**		
Course Code: **CH-361**		
Course Type: **Discipline Elective - IV**		
Contact Hours/Week: **3L**		Course Credits: **03**

Course Objectives

- To discuss the basic concepts of colloids, surface and interfacial energies and tensions, intermolecular and surface forces, stability of colloids.
- To enable the students to solve the problems effectively in the field of Chemical Engineering, Analytical and Physical Chemistry, Biochemistry and Environmental Science, Materials Science, Petroleum Engineering and Nanotechnology.

Unit Number	Course Content	Lectures
UNIT-01	**Basic concepts of colloids and interfaces:** Introduction; examples of interfacial phenomenon, solid fluid interfaces, colloids: colloids and interfaces, classification of colloids, electric charge on colloidal particles, stability of colloids, kinetic and thermodynamic stabilities, preparation of colloids, parameters of colloidal dispersions	**06 L**
UNIT-02	**Properties of colloidal dispersions:** Sedimentation under gravity and in a centrifugal field, Brownian motion, osmotic pressure, optical properties: light scattering, TEM, SEM, DLS, SANS; electrical properties: reciprocal relationship and Zeta-potential; properties of lyophilic sols, rheological properties of colloidal dispersions: Einstein's equation of viscosity, Mark-Houwink equation of polymer solutions	**08 L**
UNIT-03	**Surfactants and their properties**: Surfactants and their properties: anionic surfactants, cationic surfactants, zwitterionic surfactants, nonionic surfactants, gemini surfactants and biosurfactants, micellisation of solutions, thermodynamics of micellisation, kraft point and cloud points, HLB, liquid crystals, emulsions and microemulsions, foams	**06 L**
UNIT-04	**Surface and interfacial tensions**: Surface tension, interfacial tension, contact angle and wetting, shape of surfaces and interfaces: radius of curvature, Young-Laplace equation, pendant and sessile drops, capillary rise or depression, Kelvin equation; measurement of surface and interfacial tension: drop-weight, du Nouy ring, wilhelmy plate, maximum bubble pressure, spinning drop; measurement of contact angle	**08 L**
UNIT-05	**Intermolecular and surface forces:** Van der walls forces: macroscopic bodies, Derjaguin approximation, Hamaker constant, disjoining pressure; electrostatic double layer force: models, mathematical modeling of diffuse layer, limitation of Poisson-Boltzmann equation, DLVO theory, non DLVO forces, steric forces by adsorbed polymer	**08 L**

Course Outcomes

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

CO1: Understand the basics properties of the colloids, interfaces and explain their applications.
CO2: Understand the particle aggregation behavior in aqueous and organic dispersions.
CO3: Design a colloidal dispersion having long-term stability.
CO4: Prepare emulsions and microemulsions with the use of surfactants and polymers.
CO5: Understand the engineering aspects of fluid-fluid interfaces, fluid-solid interfaces and surface energy.

Books and References

1. An Introduction to Interfaces and Colloids: The Bridge to Nanoscience by J. C. Berg, World Scientific, Singapore, 2009.
2. Colloid and Interface Science by P. Ghosh, PHI Learning, 2009.
3. Principles of Colloid and Surface Chemistry by P. C. Hiemenz, R. Rajagopalan, Marcel Dekker, 1997.
4. J. N. Israelachvili, Intermolecular and Surface Forces, Academic Press, Elsevier, 2003
5. Physical Chemistry of Surfaces by A. W. Adamson, A. P. Gast, John Wiley & Sons, 1997.
6. Interfaces and Colloids: Principles and Applications by D. Myers, Surfaces, 2nd edition, Wiley-VCH, 1999.
7. Foundations of Colloid Science by R. J. Hunter, 2nd edition, Oxford University Press, 2001.

Course Name: **Principles of Non-Newtonian Fluid Mechanics** Course Code: **CH-362** Course Type: **Discipline Elective - IV**		
Contact Hours/Week: **3L**		Course Credits: **03**
Course Objectives • To understand basic concepts of non-Newtonian fluid rheology. • The study of the flow of complex fluids such as polymers, pastes, suspensions, and foods. • To understand standard flows for rheology, material functions, and experimental data.		
Unit Number	**Course Content**	**Lectures**
UNIT-01	**Introduction: Introduction:** Effects and phenomena in non-Newtonian fluid mechanics, Shear-Thinning and Shear Thickening, Yield Stress, Elastic/Viscoelastic Effects, the Weissenberg Effect, Fluid Memory, Die Swell, Rheology as Spectroscopy,Vector and tensor operations, Overview of Newtonian fluid mechanics Process Modeling.	**08 L**
UNIT-02	**Standard flows for Non-Newtonian fluids:** Simple Shear Flow, Simple Shear-Free (Elongational) Flows, Uniaxial Elongational Flow, Biaxial Stretching Flow, Planar Elongational Flow, Forms of the Stress Tensor in Standard Flows, Simple Shear Flow, Elongational Flow, and Measuring Stresses in Standard Flows.	**07 L**
UNIT-03	**Material functions for non-Newtonian fluids**: Shear Flow, Steady Shear, Unsteady Shear, Shear-Stress Growth, Shear-Stress Decay, Shear Creep, Step Shear Strain, Small-Amplitude Oscillatory Shear, Small-Amplitude Oscillatory Shear—Complex Notation, Elongational Flow.	**08 L**
UNIT-04	**Constitutive models without memory effects – Generalized Newtonian Fluids (GNF):** GNF constitutive models, Power-Law model, Carreau-Yasuda model, Bingham model, Predictions of material functions, Flow problems, Limitations.	**07 L**
UNIT-05	**Constitutive models with memory effects – Generalized Linear Viscoelastic (GLVE) fluids**: Memory effects, Maxwell models, Generalized linear viscoelastic model (GLVE), Flow problems with GLVE constitutive model, Limitations.	**07 L**
Course Outcomes Upon successful completion of the course, the students will be able to CO1: The general features of non-Newtonian fluid mechanics. CO2: To know the behavioral aspects and dynamics of fluids that doesn't obey the Newtonian model of viscosity. CO3: To understand the different types of constitutive models for non-Newtonian fluids. CO4: Applications to solve various flow problems.		
Books and References 1. Understanding Rheology by A. Faith, Morrison, Oxford, 2001. 2. Dynamics of Polymeric Liquids by R. Byron Bird, Robert C. Armstrong and Ole Hassager - Volume 1, John Wiley and Sons, 1987.		

Course Name: **Nanomaterials and Nanofabrication**
Course Code: **CH-363**
Course Type: **Discipline Elective - IV**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart knowledge about the basic concepts of nanomaterials and nanotechnology.
- To introduce the fundamental concepts relevant to different classes of nanomaterials.
- To enable the students to understand the factors that causes the design and fabrication of nanoparticles

Unit Number	Course Content	Lectures
UNIT-01	**Introduction:** Definition of nanotechnology and nanomaterials, nanoscale dimension, history, current issues and industry applications, different classes of nanomaterials as metal and semiconductor nanomaterials, quantum dots, wells and wires, bucky balls and carbon nanotubes, self-assembly, complex adaptive systems (CAS), carbon nanomaterials	**07 L**
UNIT-02	**Synthesis Techniques:** Top-down approach, bottom-up approach, grinding, planetary milling and comparison of particles, sol-gel methods, sonochemical approach, physical vapour deposition, chemical vapour deposition, wet deposition techniques, supramolecular approach, molecular design and modelling.	**08 L**
UNIT-03	**Characterization Techniques:** Instrumentation fractionation principles of particle size measurements, particle size and its distribution, XRD, TEM, SEM and AFM technique, scanning and tunnelling microscopy, fluorescence microscopy and imaging.	**08 L**
UNIT-04	**Carbon Nanotubes:** Introduction to carbon nanotube, CNT from graphite, types of CNT, nanotubes and nano-wall structures, bucky onions nanotubes.	**05 L**
UNIT-05	**Nanofabrication:** Nanolithography, photolithography, soft lithography, thin film deposition, etching and bonding, micro-electro-mechanical systems (MEMS), challenges & future development, Industrial Applications of Nanomaterials	**07 L**

Course Outcomes

Upon successful completion of the course, the students will be able to;
CO1: Identify and understand the peculiar properties of materials at nanoscale.
CO2: Describe the chemistry involved in the synthesis and fabrication of nanomaterials.
CO3: Apply principle of nanotechnology to understand the properties of nanomaterials.
CO4: Assess the importance of applications of nanomaterials in related fields.

Books and References

1. Introduction to Nanoscience and Nanotechnology by G.L. Hornyak, H.F. Tibbals, J. Dutta, and J.J. Moore, CRC Press, 2009.
2. Introduction to Nanotechnology by C. Poole, and F. Owens, Wiley India, 2007.
3. Nanoscale Science and Technology by R. Kelsall, I.M. Hamley, and M. Geoghegan, John Wiley, 2005.
4. NANO: The Essentials: Understanding Nanoscience and Nanotechnology by T. Pradeep, McGraw Hill, 2007

Course Name:	**Introduction to Molecular Simulation**
Course Code:	**CH-364**
Course Type:	**Discipline Elective - IV**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives:

- To impart knowledge about the basic concepts of molecular simulation.
- To introduce the fundamental concepts relevant to different computational techniques.
- To enable the students to understand the factors those cause the computation of different thermodynamic properties.

Unit Number	Course Content	Lectures
UNIT-01	**Concepts of Statistical Mechanics:** Molecular Mechanics, Statistical Ensemble, Phase Space, Thermodynamic Limit, Trajectory, atomic and molecular interaction	**07 L**
UNIT-02	**Entropy and equation of State:** Definition of Entropy, Ideal Gas Entropy, Mechanical and Chemical Coupling, Fundamental Equation of State, Ideal Gas Law, Virial Equation of State	**08 L**
UNIT-03	**Partition functions and ensembles:** Partition function, Micro-caninical ensemble, canonical ensemble, Boltzmann distribution	**06 L**
UNIT-04	**Short range Interactions:** Repulsive Interaction, Dispersive Interaction, Lennard-Jones Potential, Unlike Interaction, Long range Interactions: Electrostatic Interactions, Force Field Design, Separation of Scales; Molecular	**09 L**
UNIT-05	**Simulation Algorithms:** Molecular Dynamics, Thermostat and Barostat, Monte Carlo Method, Metropolis Algorithm	**05 L**

Course Outcomes

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

CO1: Identify and understand the peculiar molecular simulation techniques.

CO2: Describe the different simulation techniques to compute the entropy, Gibbs and Helmohltz free energy, etc.

CO3: Apply and adopt the suitable molecular simulation techniques for proposed thermodynamic system.

CO4: Assess the importance of applications of molecular simulation techniques in related fields.

Books and References

1. Computer Simulation of Liquids by M. P. Allen, D. J. Tildesley, Clarendon Press.
2. Understanding Molecular Simulation: From Algorithm to Application by D. Frenkel, B. Smit, Academic Press.
3. Physical Chemistry, a Molecular Approach by D. McQuarrie, J. D. Simons, University Science Books.
4. Introduction to Modern Statistical Mechanics by D. Chandler, Oxford University Press.
5. Introduction to Statistical Thermodynamics by T. L. Hill, Addison-Wesley.

Course Name: **Computational Fluid Dynamics** Course Code: **CH-365** Course Type: **Discipline Elective - IV**		
Contact Hours/Week: **3L**		Course Credits: **03**

Course Objectives

- To develop an understanding for the major theories, approaches and methodologies used in CFD.
- To impart knowledge about the application of CFD analysis to real engineering designs.
- The CFD techniques can be applied for solving practical problems in fluid flow, heat and mass transfer.
- To equip students with the knowledge of using commercial software package.

Unit Number	Course Content	Lectures
UNIT-01	**Introduction to Computational Fluid Dynamics:** Introduction of CFD, Applications, comparison between numerical, analytical and experimental approaches, modelling versus experimentation.	**02L**
UNIT-02	**Principles of Conservation**: Fundamental principles of conservation, Reynolds transport theorem, conservation of mass, conservation of linear momentum: Navier-Stokes equation, conservation of energy, general scalar transport equation.	**03L**
UNIT-03	**Classification of Partial Differential Equations:** Mathematical classification of partial differential Equation, physical and mathematical classifications of PDEs, systems of partial differential equations, boundary conditions.	**05L**
UNIT-04	**Finite Difference Method:** Discretization principles, truncation and round-off error, explicit and implicit approaches, basic of finite difference method, treatment of boundary conditions, assessing accuracy and stability of numerical methods, finite difference applications in heat conduction and convection: steady heat conduction in rectangular geometries, convective heat transfer, stream function formulation.	**07L**
UNIT-05	**Finite Volume Method:** Discretization methods, the four basic rules, one-dimensional steady and unsteady diffusion problems, two and three dimensional situations, convection and diffusion for one-dimensional steady problems, various discretization schemes, solution of discretized equations, pressure and velocity corrections, pressure velocity coupling	**07L**

Course Outcomes

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

CO1: Understand the general form and solution strategy for transport phenomena problem

CO2: Develop an understanding through examples of how the general form is converted to a specific solutions

CO3: Review and recall how the basic vector and matrix operators are used in defining Transport Phenomena problems

CO4: Understand the concept of diffusive transport of conserved quantities: Fick's Law, Fourier's Law, Newton's Law

CO5: Become familiar with the general expression for diffusive flux of a conserved quantity

Textbooks and References

1. Transport Phenomena by R. B. Bird, W. E. Stewart, E. E. Lightfoot, 2nd edition, John Wiley & Sons, 2007.
2. Analysis of Transport Phenomena by W. M. Deen, 2nd edition, Oxford University Press, 2013.

Course Name: **Energy Technologies** Course Code: **CH-381** Course Type: **Stream Core-I**		
Contact Hours/Week: **2L**		Course Credits: **02**
Course Objectives • To understand various non- renewable energy resources. • To understand various novel energy resources • To understand efficient utilization of non- renewable energy resources.		
Unit Number	**Course Content**	**Lectures**
UNIT-01	**Non-Renewable Energy Resources :** **Solid Fuels- coal:** Classification of coal based upon rank, Seylor's classification, Proximate & ultimate analysis, briquetting. **Liquid Fuels- :** classification and characteristics of Petroleum crude, properties and characteristics of Petroleum Products - motor gasoline, aviation gasoline, kerosene, diesel oil **Gaseous Fuel*s:*** producer gas, water gas, coal gas, CNG, LPG	**10L**
UNIT-02	**Renewable Energy Resources :** **Solar Energy:** Instruments for measuring solar radiations, Flat plat and concentrating collectors, classification of concentrating collectors, solar applications: Solar heating/cooling technique, solar distillation and drying, photovoltaic energy conversion. **Wind Energy**: Sources and potentials, horizontal and vertical axis, wind mills, wind regime analysis and evaluation of wind mills.	**09L**
UNIT-03	**Novel Energy Resources** : Shale Gas, Coal bed methane, Oil sands, Gas hydrates , Energy crops	**05L**
Course Outcomes Upon successful completion of the course, the student will be able to CO1: Demonstrate the knowledge of various conventional fossil fuels and their derivative fuels. CO2: Understand the solar energy operation and its characteristics CO3: Educate the wind energy operation and its types		
Textbooks and References 3. Sarkar S. Fuels and Combustion, 2nd Ed., Orient Longman, 2003. 4. Gupta O.P., Elements of Fuels, Furnaces and Refractories, Khanna Publications, 1997. 5. Francis, W., Peters M.C., Fuels and Fuel Technology: a Summarized Manual, 2nd Ed., Pergamon Press, 1980 6. Rai G D, Non-Conventional Energy Sources, 4th edition, Khanna Publishers, 2009 7. Sarma A., Fundamentals of Coalbed Methane, Scitus Academics LLC, 2016. 8. Carroll J., Natural gas hydrates: A guide for engineers, Gulf Professional Publishing, 2009.		

Course Name: **Mass Transfer Lab**
Course Code: **CH-324**
Course Type: **Discipline Core**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives

- To make students understand and apply the basics of mass transfer.
- To provide hands-on experience to the students in working with Stefan tube, VLE set-up, Cooling tower, Plate and packed column, welted wall column etc.
- To enable the student to report and analyze data obtained from different set-up.

List of Experiments

1. Determination the number of theoretical plates and plate efficiency in sieve plate distillation column.
2. Determination of packed-bed height in a packed bed distillation column.
3. Study of heat and mass transfer in water cooling tower.
4. Study the dissolution of benzoic acid with and without chemical reaction.
5. Measurement of diffusivity for organic solvents using Stefan tube.
6. Estimation of mass transfer coefficient in wetted wall column.
7. Estimation of distillation characteristics of petroleum oils/organic solvents.
8. Study of vapour-liquid Equilibria (VLE) for two components system.
9. Determination of extraction coefficient for liquid-liquid extraction in a packed tower.
10. Determination of leaching coefficient solid -liquid extraction study in packed column.
11. Study the drying characteristics curve under constant drying condition in rotary vacuum or tray dryer.
12. Study and verify the Raleigh equation for batch distillation.
13. Determination of mass transfer coefficient for absorption in packed column
14. Study the humidification and dehumidification characteristics.
15. Estimation of flux and separation factor in membrane filtration (UF/NF).
16. Estimation of crystallization efficiency in batch crystallizer.

N.B.: List of experiments will be finalized by the course instructor at the beginning of the semester.

Course Outcomes

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

CO1: Determine diffusivity and mass transfer coefficient for various systems.
CO2: Describe phase, VLE diagrams, batch distillation, humidification operation and drying rate curve.
CO3: Apply principles of McCabe-Thiele to estimate the No. of plates in plate column and HETP for packed column.
CO4: Estimate the cooling tower characteristics, efficiency of liquid-liquid and solid-liquid extractors.

Course Name: **Energy Technologies Lab**
Course Code: **CH-325**
Course Type: **Discipline Core**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives

- To define the fundamental concepts in energy technology.
- To recognize the practical significance of various parameters related to various energy resources.
- To apply the knowledge of energy technology in an effective manner for different applications.

List of Experiments

1. To determine the proximate and ultimate analysis of coal.
2. To determine the performance of solar water heaters.
3. To determine the flash and fire point of sample oil using Pensky Marten's apparatus.
4. To determine the flash and fire point of kerosene using Abel apparatus.
5. To determine the Cloud and Pour point of a given sample.
6. To determine the Aniline point of a given sample.
7. To determine the viscosity of petroleum products and lubricants by Saybolt viscometer apparatus.
8. To produce biogas from the waste biomass.
9. To characterize and determine properties of gasoline i.e. density, specific gravity etc.
10. To study the solar heater.
11. To study solar photovoltaic system.

Course Outcomes

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

CO1: Determine the calorific values, proximate and ultimate analysis of fuels.

CO2: To determine the flash, fire, Aniline Cloud and Pour points.

CO3: Synthesize biogas from waste.

CO4: To characterize the petroleum products by measuring their density, viscosity, specific gravity etc.

CO5: Understand the working of solar energy devices.

SEMESTER-VII

Course Name: **Process Plant Design and Economics**
Course Code: **CH-411**
Course Type: **Discipline Core**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To teach basic concepts of a chemical process and plant design.
- To familiarize with hierarchical approaches in process and plant design.
- To understand concepts of economic balances and economic analysis of process plant.
- To familiarize with the commercial flow sheet making software (ASPEN Plus®) to simulate chemical processes.

Unit Number	Course Content	Lectures
UNIT-01	**Process Selection, Strategy for Synthesis and Analysis:** Aspects of process design, pre-project objectives, project classification, block flow diagram (BFD), process flow diagram (PFD), piping and instrumentation diagram (P&ID), conceptual design and synthesis of a process flow diagram, development of PFD from generic BFD for a case study using ASPEN HYSYS/ ASPEN Plus®.	**07 L**
UNIT-02	**Process Economics:** Estimation of capital costs, purchased equipment costs, the total capital cost of a plant, bare module cost-base and non-base conditions, estimation of manufacturing costs, cost of labor, utility cost, raw material costs, depreciation, annuity, time value of money, different process/ project profitability measures, profitability measures of a case study.	**06 L**
UNIT-03	**Hierarchical Approach in Process Design:** Batch versus continuous processes, comparative analysis, input information, decisions for input-output structure, overall material balance, stream costs, process alternatives, decision for the recycle structure, equilibrium limitations, modifications of reactor design for recycle, equipment costs associated with recycle, overall economic potential of process with recycle, general structure of the separation system, location of vapor and liquid recovery system in the process, sequencing of non-integrated distillation columns for minimum vapor load, thermal coupling of columns, application of hierarchical approach in different case studies.	**07 L**
UNIT-04	**Heat Exchanger Network Synthesis:** First law analysis, cascade diagrams, temperature-enthalpy diagrams, grand composite curve, multiple utilities, area estimates, design of MER Networks, loops and paths, stream splitting, heat and power integration.	**08 L**
UNIT-05	**Cost Diagrams and Quick Screening of Process Alternatives:** Concept of cost diagram, quick assessment of cost distribution, cost allocation procedures, lumped cost diagram, screening of process alternatives with cost diagrams using design heuristics.	**05 L**

Course Outcomes

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

CO1: Develop a chemical process from scratch.
CO2: Perform preliminary feasibility study of the proposed chemical plant.
CO3: Perform a complete economic analysis of the proposed chemical plant to calculate total capital investment product cost and profitability of the overall process.
CO4: Use commercial flow sheet making software to simulate chemical processes.

Books and References

1. Plant Design and Economics for Chemical Engineers by M.S. Peters, and K.D. Timmerhaus, R.E. West, 5th edition, McGraw Hill, 2017.
2. Conceptual Design of Chemical Processes by J.M. Douglas, McGraw Hill, 1988.
3. Product & Process Design Principles: Synthesis, Analysis, and Evaluation by W.D. Seider, J.D. Seader, and D. R. Lewin, 2nd edition, Wiley-India Edition, 2004.
4. Chemical Engineering by R.K. Sinnot, J.M. Coulson, and J.F. Richardson,Vol.-6, Revised 2nd edition, Butterworth-Heinemann, 1996.
5. Analysis, Synthesis, and Design of Chemical Processes by R. Turton, R.C. Bailie, W.B. Whiting, J.A. Shaeiwitz, and D. Bhattacharyya, 4th edition, Prentice Hall, 2013.

Course Name: **Process Equipment Design-II**
Course Code: **CH-412**
Course Type: **Discipline Core**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To apply the basic principles/concepts learned in the subjects of Fluid Mechanics, Heat Transfer, Mass Transfer, and Mechanical Operation in the mechanical and process design of chemical process equipment.
- To develop the skill to select and design the appropriate process equipment for the required unit or process operation.
- To analyze and evaluate the performance of existing equipment.

Unit Number	Course Content	Lectures
UNIT-01	**Process Design of Heat Exchanger:** Heat exchanger classification, thermal design consideration, design procedure of shell and tube heat exchanger for two phase heat transfer, design of condenser and reboiler.	**07 L**
UNIT-02	**Mechanical Design of Heat Exchanger:** Design standards of shell and tube heat exchanger, design temperature and pressure, materials of construction, design of different components (shell, channel cover, tube, baffles, nozzles etc.) of shell and tube heat exchanger.	**06 L**
UNIT-03	**Design of Evaporator:** Thermal design of single and multiple effects evaporators, calculation of tube-side and shell-side pressure drop; calculation of intermediate temperatures of multiple effects evaporator; estimation of overall heat transfer coefficients.	**07 L**
UNIT-04	**Design of Dryer:** Calculation of process design variables of rotary dryer such as inlet and exit moisture contents of the solid; the critical & equilibrium moisture contents; temperature and humidity of the drying gas.	**08 L**
UNIT-05	**Design of Mass Transfer Columns:** Effect of vapor flow conditions of tray design, column sizing approximation, detailed design of tray, Column construction and internals, different stresses (axial, circumferential and compressive) induced in column and its calculations.	**05 L**

Course Outcomes

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

CO1: Integrate the knowledge acquired from chemical engineering courses in the design of equipment.
CO2: Design heat exchangers, condensers, reboilers, evaporators and dryers.
CO3: Design and analyze tray columns.
CO4: Apply mechanical design aspects to process equipment.

Books and References

1. Chemical Equipment Design by B.C. Bhattacharya, CBS Publisher, 1985.
2. Process Heat Transfer by D.Q. Kern, McGraw Hill, 2001.
3. Joshi's Process Equipment Design by V.V. Mahajani, and S.B. Umarji, 5th edition, Laxmi Publications, 2016.
4. Chemical Engineering by R.K. Sinnot, J.M. Coulson, and J.F. Richardson, Vol.- 6, Butterworth Heinemann, 1998.
5. Applied Process Design for Chemical and Petrochemical Plants by E.E. Ludwig, Vol. - 1, 2 & 3, Gulf Publishing Company, 1995.
6. Perry's Handbook of Chemical Engineering by D.W. Green, and R.H. Perry, McGraw Hill, 1997.
7. Ludwig's Applied Process Design for Chemical and Petrochemical Plants by A.K. Coker, Vol.-1, 2 & 3), Gulf Professional Publishing Vol. -1 (2007); Vol. -2 (2010); Vol- 3.

Course Name: **Process Modeling and Simulation** Course Code: **CH-413** Course Type: **Discipline Core**		
Contact Hours/Week: **3L**		Course Credits: **03**
Course Objectives • To introduce basic concepts and types of models. • To develop mathematical models of chemical engineering systems using fundamental conservation laws. • To develop simulation strategies for chemical process models.		
Unit Number	**Course Content**	**Lectures**
UNIT-01	**Introduction:** Modeling and simulation, classification, uses of mathematical models and tools, physical and mathematical modeling, deterministic and stochastic process, types of modeling equations, and classification of models (lumped parameter models, distributed parameter models).	**09 L**
UNIT-02	**Mathematical Models:** principles of model formulation, fundamental laws-continuity equation, energy equation, equations of motion, transport equations, equations of state, equilibrium and kinetics, constitutive relationships, dimensionless analysis, degree-of-freedom analysis.	**06 L**
UNIT-03	**Lumped Parameter Models:** Series of isothermal constant holdup CSTRs, CSTRs with variable holdups, non-isothermal CSTR, batch reactor, batch distillation with holdup, ideal binary distillation column, gas absorber, interacting and non-interacting tanks, gravity flow tank, single and multiple effect evaporator systems.	**10 L**
UNIT-04	**Distributed Parameter Models:** Convective problems, laminar flow of Newtonian liquid in a pipe, diffusive problems, combined convective and diffusive problems, model for Heat exchanger.	**07 L**
UNIT-05	**Simulation:** Solution strategies for Ordinary differential equations: linear, non-linear, initial value problems and final value problems. Solution strategies for distributed parameter models: parabolic, elliptic and hyperbolic partial differential equations. Basic simulation of chemical models using MATLAB.	**08 L**
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Develop mathematical model of a chemical engineering system using fundamental laws. CO2: Carry out DOF analysis of chemical process model. CO3: Identify chemical processes as steady, unsteady, lumped, distributed parameter models. CO4: Develop strategies to find the solution of chemical process models.		
Books and References 1. Process Modeling Simulation and Control for Chemical Engineers by W.L. Luyben, McGraw Hill, 2013. 2. Introduction to Chemical Engineering Analysis by T.W.F Russell, and M.M. Denn, John Wiley & Sons, 1972. 3. Process Dynamics- Modelling, Analysis and Simulation by Bequette, PHI International, 2003. 4. Chemical Reactor Design for Process Plants by H.F. Rase, Vol II: Case Studies and Design Data, 1st Ed., John Wiley and Sons, New York, 1997.		

Course Name: **Optimization of Chemical Processes** Course Code: **CH-431** Course Type: **Discipline Elective - V**		
Contact Hours/Week: **3L**		Course Credits: **03**
Course Objectives • To apply optimization techniques in chemical engineering process and design problems.		
Unit Number	**Course Content**	**Lectures**
UNIT-01	**Introduction:** Introduction to optimization and its scope in chemical process design, Organization of optimization problems, The Essential features of optimization problems, General procedure for solving optimization problems, Obstacles to optimization.	**04 L**
UNIT-02	**Classical Optimization Techniques**: One dimensional minimization method, Elimination methods- equally spaced points method, Fibonacci method and golden section method; Interpolation methods-quadratic interpolation and cubic interpolation, Newton and quasi-Newton methods.	**08 L**
UNIT-03	**Linear Programming and Applications:** Basic concepts in linear programming, Graphical Solution, Simplex methods, Sensitivity analysis, Duality in linear programming, Transportation Problem.	**08 L**
UNIT-04	**Multivariable Non–Linear Programming:** Unconstrained-univariate method, Powell's method, simplex, method, rotating coordinate method, steepest descent method, Fletcher Reeves method, constrained-complex method, feasible directions method, GRG method, penalty function methods and augmented Lagrange multiplier method.	**08 L**
UNIT-05	**Application of Optimization:** Heat transfer and energy conservation, Separation processes, Fluid flow systems, Chemical reactor design and operation.	**08 L**
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Formulate a chemical engineering optimization problem. CO2: Apply suitable optimization technique to solve the problem. CO3: Develop some numerical code for a complex optimization problem.		
Books and References 1. Optimization of Chemical Processes by T.F. Edgar, D.M. Himmelblau, and L.S. Lasdon, 2nd edition, McGraw Hill, 2001. 2. Engineering Optimization Theory and Practice by S.S. Rao, 3rd edition, New Age International Publishers, 2016. 3. Engineering Optimization, Methods and Applications by A. Ravindran, K.M. Ragsdell, and G.V. Reklaitis, 2nd edition, John Wiely, 2006.		

Course Name: **Polymer Science and Engineering** Course Code: **CH-432** Course Type: **Discipline Elective - V**		
Contact Hours/Week: **3L**		Course Credits: **03**
Course Objectives • To impart knowledge about industrial manufacturing processes. • To introduce the fundamental knowledge about polymerization reaction kinetics. • To enable the students about technology and application of commodity of plastics.		
Unit Number	**Course Content**	**Lectures**
UNIT-01	**Introduction:** Concepts and classification of polymers Functionality, Glass transition temperature, Addition, condensation, step- growth and chain – growth polymerization. Molecular weight estimation: Average molecular weight – number and weight average, Sedimentation and viscosity average molecular weights, Molecular weight and degree of polymerization, poly dispersity index, significance of molecular weight.	**09 L**
UNIT-02	**Polymerization Processes:** Bulk, solution, emulsion and suspension polymerization, Comparison of polymerization processes	**05 L**
UNIT-03	**Polymerization Kinetics:** Chemistry of step reaction polymerization, mechanism and kinetics of polycondensation reactions and free-radical chain polymerization, chain transfer agents, Ziegler Natta polymerization processes and differentiation based on kinetics of anionic and cationic polymers.	**07 L**
UNIT-04	**Synthetic Fibres:** Types of fibres, spinning techniques, manufacturing technology and applications of different types of fibres: cellulosic fibres, polyamides, acrylics, vinyls and vinylidines, fluorocarbons.	**07 L**
UNIT-05	**Plastics:** Molding techniques for plastics: injection molding, compression molding, calendaring, blow moulding, extrusion, thermoforming, and applications of different types of plastics: polyester, polyethylene, phenolics, rubbers, structure, properties and preparation natural rubber synthetic rubbers: SBR, rubber compounding and reclaiming.	**08 L**
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Able to understand the basic classification of polymers. CO2: Analyze the various techniques of carrying out polymerization. CO3: Determine the molecular weight of polymers. CO4: Describes the various polymer processing techniques.		
Books and References 1. Polymer Science by V.R. Gowariker, N.V. Viswanathan, and J. Sreedhar, New Age International Publishers, 1996. 2. Text Book of Polymer Science by F.W. Billmeyer, Wiley Tappers, 1994. 3. Polymer Science and Technology of Plastics and Rubber by P. Ghosh, Tata McGraw Hill, 2001. 4. Fundamentals of Polymer Engineering by R.K. Gupta, and A. Kumar, 2nd edition, Marcel Dekkar, 2003.		

Course Name: **Biomass Valorization Technologies**		
Course Code: **CH-433**		
Course Type: **Discipline Elective - V**		
Contact Hours/Week: **3L**		Course Credits: **03**

Course Objectives

- To understand the important information on bioenergy.
- To acquire knowledge on cutting-edge technologies for conversion of various biomass feedstocks to bioenergy/biofuel.
- To contribute towards providing biomass-based sustainable energy solutions.

Unit Number	Course Content	Lectures
UNIT-01	**Introduction to bioenergy**; biomass harvesting; availability and assessment of biomass for bioenergy applications; characterization of biomass feedstock (Physico-chemical properties, ultimate, proximate, compositional, calorific value, thermo gravimetric, differential thermal and ash fusion temperature analyses).	**08 L**
UNIT-02	**Classification of biomass feedstock:** first, second and third generation biofuels; hybrid biofuels, basic principles of chemical thermodynamics; carbon-neutral fuels	**06 L**
UNIT-03	**Bio-Chemical conversion routes:** pre-treatment processes of biomass; different production routes for biomass conversion to biofuels, aerobic, anaerobic, enzymatic- saccharification and fermentation process	**06 L**
UNIT-04	**Chemical conversions**: transesterification**,** hydro-processing, thermochemical methods (combustion, gasification, pyrolysis, partial oxidation) for biofuels production including synthesis gas, bio-hydrogen, ethanol, biogas, methanol.	**06 L**
UNIT-05	**Biomass compaction:** briquetting and palletisation; biofuel quality up-gradation; Biomass-based incineration plant for heat generation; cofiring of biomass for heat generation for industrial processes; Biomass fuelled combustion devices for cooking and heating applications.	**06 L**

Course Outcomes

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

CO1: Classification and characterization of biomass feedstock

CO2: Compare the different production routes for biomass conversion to biofuels

CO3: Understand various technologies for biomass compaction

Books and References

1. Jay J. C., Biomass to Renewable Energy Processes, Taylor and Francis, CRC Press, 2018
2. Konur O., Bioenergy and Biofuels, Taylor and Francis, CRC Press, 2018
3. Henderson O. P., Biomass for Energy, Nova Science Publishers, 2011
4. Mukunda, H. S., Understanding Clean Energy and Fuels from Biomass, Wiley India, 2011.

Course Name: **Introduction to Statistical Thermodynamics**
Course Code: **CH-434**
Course Type: **Discipline Elective - V**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart knowledge about the basic concepts of statistical thermodynamics.
- To introduce the fundamental concepts relevant to entropy, Gibbs and Helmohltz free energy, etc.
- To enable the students to understand the factors that causes the thermodynamic issues in any chemical process by different computational techniques.

Unit Number	Course Content	Lectures
UNIT-01	**Introduction:** Elementary statistical mechanics, postulates of statistical mechanics, quantum mechanical aspects, Boltzmann's distribution law, isolated system, entropy, microscopic and macroscopic properties, microscopic and macroscopic descriptions of the state of a system	**06 L**
UNIT-02	**Partition functions and probability:** Partition functions, derivatives and thermodynamic properties, system of independent particles, compressibility equation, thermodynamic probability, probability distribution; **Ensembles Averages:** Canonical, microcanonical, and grand canonical ensemble, NVE, NVT, NPT, μVT, Equivalence of ensembles	**09 L**
UNIT-03	**Fluctuations and equilibration:** Fluctuation, energy, density, pressure, entropy maximization, configurational integral, Virial equation of state, ideal and non-ideal monoatomic and polyatomic gases, particle densities, thermal equilibrium, chemical equilibrium in ideal gas mixtures	**08 L**
UNIT-04	**Distribution functions:** Distribution functions theories, perturbation theories, molecular distribution functions, density expansion of pair correlation function, direct correlation function, lattice models, average energy, compressibility	**07 L**
UNIT-05	**Applications through simulations:** Thermo-physical property calculations, study of phase equilibria, Gibbs ensemble, thermodynamic integration, free energy evaluation by molecular simulation techniques, surface adsorption, adsorption isotherms, molecular interaction.	**05 L**

Course Outcomes

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

CO1: Identify and understand the peculiar thermodynamic properties.

CO2: Describe the different computational techniques to compute entropy, Gibbs and Helmohltz free energy, etc.

CO3: Apply principle of statistical thermodynamics to understand the equilibrium phenomena.

CO4: Assess the importance of applications of statistical mechanics in related fields.

Books and References

1. An Introduction to Statistical Thermodynamics by T.L. Hill, Dover Publications Inc.; New edition, 2003.
2. Statistical Physics by L.D. Landau, and E. M. Lifshitz, Butterworth-Heinemann Ltd; 3rd edition, 1996.
3. Statistical Mechanics by A. McQuarrie, University Science Books.
4. Applied Statistical Mechanics by T.M. Reed and K.E. Gubbins, McGraw-Hill Inc., 1973.
5. Thermodynamics and Statistical Mechanics: Equilibrium by Entropy maximisation by P. Attard, Academic Press, Elsevier, 2002.

Course Name: **Novel Separation Processes**
Course Code: **CH-435**
Course Type: **Discipline Elective - V**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To demonstrate the fundamentals of novel separation processes.
- To enable the students to select various novel separation processes.
- To impart the knowledge about designing a separation process unit.

Unit Number	Course Content	Lectures
UNIT-01	**Fundamentals of Separation Processes and Membrane Separation Processes:** Mechanisms of phase separation, selection of feasible separation process, various novel separation processes, principles of membrane separation, classification, analysis and modeling of membrane separation, osmosis, nanofiltration, microfiltration and ultrafiltration, membrane characteristics and applications, ion selective membranes and their application in electrolysis, dialysis and electro dialysis, pervaporation and gas separation, Liquid membrane, membrane casting, characterization.	**12 L**
UNIT-02	**Surfactant Based Separation Processes:** Foam and bubble separation, principle, classification, foam and surfactants, separation techniques, column separations.	**06 L**
UNIT-03	**Electrophoretic Separation Methods:** Forces in electrophoresis, factors influencing electrophoresis, gel membrane and paper electrophoresis, zonal electrophoresis.	**06 L**
UNIT-04	**Supercritical Fluid Extraction (SCF):** Critical conditions, supercritical solvents, parameters in SCF, basic technique.	**05 L**
UNIT-05	**Ion Exchange and Chromatographic Separation Processes:** Principles and practice, classification of chromatographic techniques, gel filtration, ion exchange chromatography and chromate-focusing, reversed phase and hydrophobic interaction chromatography, affinity chromatography.	**07 L**

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1: Select a suitable separation process for a desired application.
CO2: Design the separation process selected.
CO3: Can develop hybrid systems for more advanced separation.
CO4: Can apply separation techniques to biological systems.

Books and References

1. Separation Processes by C.J. King, McGraw Hill, 2013.
2. Separation Process Principles by J.D. Seader, E.J. Henley, and D.K. Roper, John Wiley, 2015.
3. Basic Principles of Membrane Technology by J. Mulder, Springer; 2nd ed. 1996.
4. Water Purification by Ion Exchange by T.V. Arden, Springer, 1968.
5. Unit Operations of Chemical Engineering by W.L. McCabe, J.C. Smith, and P. Harriott, McGraw Hill, 2017.
6. Handbook of Separation Process Technology by R.W. Rousseau, Wiley-Blackwell, 1987.
7. Transport Phenomena and Separation Process Principles by J. Genkoplis, PHI, 2015.

Course Name: **Petrochemical Technology** Course Code: **CH-436** Course Type: **Discipline Elective - V**
Contact Hours/Week: **3L** Course Credits: **03**
Course Objectives: • To impart knowledge about the statistical methods used in analyzing the data from analytical instruments. • To introduce the fundamentals of analytical instruments used in chemical industries. • To enable the student to identify the suitability of a particular analytical method(s) based on its merits, demerits, and limitations and to interpret the output data in required form.

Unit Number	Course Content	Lectures
UNIT-01	**Petrochemical Industry:** Indian Petrochemical Industry, Feedstocks, nature and effect of different types of refinery feedstock and impurities, refinery configuration and operation Process description and Process variables, Naphtha cracking, reforming, unit operations in petrochemicals industry.	**08 L**
UNIT-02	**Petrochemicals from Natural gas& Naphtha:** synthesis gas, hydrogen, acetylene, ethylene, propylene, butylene, aromatics and naphthenes, Methanol, Formaldehyde, Ethylene oxide, Ethylene Glycol, Isopropanol, Acetone, Butadiene, Maleic Anhydride, benzene, toluene, xylene.	**09 L**
UNIT-03	**Petrochemicals from Aromatics:** Cumene, Styrene, LAB, Bisphenol A, Terephthalic Acid, Phthalic Anhydride	**06 L**
UNIT-04	**Polymer Based Industries:** Plastic, production of thermoplastic and thermosetting resins such as polyethylene: LDPE, LLDPE, HDPE, polypropylene, phenolic resins and epoxy resins, Polymers and their applications in engineering practice, Polyamides, polyesters and acrylics from monomers, Production of natural and synthetic rubbers, Nylon.	**08 L**
UNIT-05	**Offsite Facilities and Utilities:** Offsite facilities, layout of petrochemical plant, Off-gas treatment, effluent water treatment.	**05 L**

Course Outcomes:

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

CO1: To describe the status of petrochemical industry in India together its present and future feed stocks and their production.

CO2: To identify various petrochemicals and their production techniques and associated challenges.

CO3: To know about various petrochemicals from aromatics and their separation.

CO4: To gain the knowledge of various thermosetting and thermoplastic value-added petrochemicals and learn their production techniques.

Books and References:

1. Handbook of Petrochemicals Production Processes by R.A. Meyers, 2nd Edition, McGraw-Hill, 2019.
2. Petrochemical Process by A. Chawvel, G. Lefebvre, Vol. I & II, Gulf Publishing Co., Houston, London.
3. Petrochemical Process Technology by I.D. Mall, Macmillan India Limited, 2007.
4. Chemicals from Petroleum by A.L. Waddams, 4th edition, Gulf Publishing Company, London, 1980.
5. A Text on Petrochemicals by B.K.B. Rao, 2nd edition, Khanna Publishers, 1998.
6. Fundamentals of Petroleum and Petrochemical Engineering by U. Ray Chaudhuri, CRC Press, 2010.

Course Name: **Industrial Pollution Abatement**
Course Code: **CH-451**
Course Type: **Stream Core - II**

Contact Hours/Week: **2L** Course Credits: **02**

Course Objectives

- To understand the important issues and their abatement principles of industrial pollution.

Unit Number	Course Content	Lectures
UNIT-01	**Introduction:** Industrial pollution, Different types of wastes generated in an industry, Different water pollutants, Air pollutants and solid wastes from industry.	**04 L**
UNIT-02	**Water Pollution:** Identification, quantification and analysis of wastewater, Classification of different treatment methods into physico-chemical and biochemical techniques, Physicochemical methods, General concept of primary treatment, Liquid-solid separation, Design of a settling tank, Neutralization and flocculation, Disinfection, Biological methods, Concept of aerobic digestion, Design of activated sludge process, Concept of anaerobic digestion, Biogas plant layout.	**10 L**
UNIT-03	**Air Pollution:** Classification of air pollutants, Nature and characteristics of gaseous and particulate pollutants, Analysis of different air pollutants, Description of stack monitoring kit and high volume sampler, Atmospheric dispersion of air pollutants, Gaussian model for prediction of concentration of pollutant down wind direction, Plume and its behavior, Operating principles and simple design calculations of particulate control devices.	**10 L**

Course Outcomes

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

CO1: Quantify and analyze the pollution load.
CO2: Analyze/design of suitable treatment for wastewater.
CO3: Model the atmospheric dispersion of air pollutants.
CO4: Selection and design of air pollution control devices.

Books and References

1. Environmental Engineering by H.S. Peavy, D.R. Rowe, and G. Tchobanoglous, McGraw Hill International, 1985.
2. Introduction to Environmental Engineering and Science by G.M. Masters, Prentice Hall off India, 2008.
3. Wastewater Engineering by Metcalf & Eddy, Tata McGraw-Hill Education Private Limited, 2009.
4. Environmental Pollution Control Engineering C.S. Rao, Wiley Eastern, 2010.
5. Air Pollution Control Engineering by N. De Nevers, McGraw-Hill, 2000.

Course Name: **Petroleum Refining** Course Code: **CH-471** Course Type: **Stream Core - III**		
Contact Hours/Week: 2L		**Course Credits: 02**
Course Objectives ✓ To impart knowledge about petroleum refineries and various operations carried out in it. ✓ To introduce the fundamental of various aspects of petroleum products. ✓ To enable the student to work in a petroleum refinery as chemical engineering professional.		
Unit	**Course Content**	**Lectures**
Unit – 01	**Introduction to Petroleum Industry:** Scope and purpose of refining; global and Indian refining scenario, practice and prospect, overview of the entire spectrum of the refinery products, physiochemical characteristics of petroleum and petroleum products, refinery configuration development	**08**
Unit – 02	**Refinery Distillation Processes:** Classification of crude oil, desalting and stabilization of crude, fractional distillation of crude oil, ASTM, TBP and EFV distillation, atmospheric distillation unit, vacuum distillation unit, degree of separation (5-95 gap) and degree of difficulty of separation (Δt 50), packie charts	**10**
Unit – 03	**Fuel Refining:** Cracking, coking, reforming, alkylation, isomerisation, polymerization, sweetening, visbreaking, hydroprocessing: hydro cracking, hydro treating, hydro finishing	**12**
Course Outcomes Upon successful completion of the course, the student will be able to CO1: Identify the key problems associated with smooth operation of petroleum refinery CO2: Describe various types of solution to problems normally encountered in refineries CO3: Apply principles of distillation, product up gradation, catalysis and polymer science in industries CO4: Assess the overall performance of a petroleum refinery		
Books and References 1. Petroleum Refinery Engineering by W. L. Nelson, McGraw-Hill, 1961. 2. Petroleum Refinery Distillation by R.N. Watkins, Gulf Publishing, 1979. 3. Modern Petroleum Refining Processes by B.K.B. Rao, Oxford and IBH Publishing, New Delhi, 1990. 4. Fundamentals of Petroleum and Petrochemical Engineering byU. Ray Chaudhuri, CRC Press, 2010.		

Course Name: **Industrial Pollution Abatement Lab**
Course Code: **CH-415**
Course Type: **Discipline Core**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives

- To characterize the wastewater sample.
- To monitor the air quality.
- To impart the knowledge about various pollution abatement methods.

List of Experiments

1. Determination of Total Solid, Total Dissolved Solid and Total Suspended Solid for a Given Sample.
2. Determination of Total Acidity and Total Alkalinity.
3. Determination of Total Hardness and Estimation of Chlorides.
4. Determination of Chemical Oxygen Demand (COD) of a Given Sample.
5. Determination of Dissolved oxygen (DO) in Various Sample by Winkler Method.
6. Determination of Biological Oxygen Demand (BOD) from a Given Wastewater Sample.
7. Determination of Sludge Volume Index (SVI) of a given Wastewater Sample.
8. Determination of Phosphorous in Wastewater Sample.
9. Estimation of Fluoride in a Given Sample.
10. Determination of Nitrite and Nitrate Nitrogen in Wastewater Sample
11. Determination of Ammonical and Organic Nitrogen in Wastewater Sample.
12. High Volume Sampler to Measure the Air Quality.

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1: Determine the physical parameters of wastewater sample.
CO2: Determine the chemical and biological parameters of wastewater sample.
CO3: Measure the air quality.

Text Books

1. Environmental Engineering by H.S. Peavy, D.R. Rowe, and G. Tchobanoglous, McGraw Hill International, 1985.
2. Wastewater Engineering by Metcalf & Eddy, Tata McGraw-Hill Education Private Limited, 2009.

Course Name: **Process Simulation Lab**
Course Code: **CH-414**
Course Type: **Discipline Core**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives

- To solve Process Simulation Problems of Chemical Engineering using Simulation Tools like MATLAB, ANSYS and DWSIM, etc.

List of Experiments

1. Simulation of flash drum.
2. Simulation of CSTR.
3. Simulation of PFR.
4. Simulation of a shell and tube heat exchanger.
5. Simulation of Short-cut and Rigorous distillation.
6. Simulation of Evaporator/Extractor/Absorber.
7. Simulation of complete chemical plant.
8. Dynamics and control using Dynamic Model.
9. Solving ODE/linear/non-linear algebraic equations using MATLAB SIMULINK.
10. SIMULINK for chemical engineering control.
11. CFD simulation of flow over a flat plate.
12. CFD analysis of flow through a tube.
13. Material and energy balance calculations
14. To calculate the overall heat transfer coefficient of a shell and tube heat exchanger
15. To design a plate heat exchanger

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1: Run the simulation softwares to solve physical problems.
CO2: Simulate various unit operation in chemical engineering.
CO3: Correlate numerical and theoretical results.

Books and References

1. Jana A.K., Chemical Process Modeling and Computer Simulation, PHI, 2008.
2. Jana A.K., Process Simulation and Control using ASPEN, PHI, 2009
3. Steven C. Chapra, Applied numerical methods with MATLAB for engineers and scientists, McGrawhill, 2012

SEMESTER-VIII

Course Name:	**Process Intensification**
Course Code:	**CH-461**
Course Type:	**Stream Elective - I**
Contact Hours/Week: **3L**	Course Credits: **03**

Course Objectives

- To cover development of various intensified technologies with a particular emphasis on their application in chemical processes.
- To design and implementation of green processing technologies based on process intensification principles.

Unit Number	Course Content	Lectures
UNIT-01	**Introduction on Process Intensification:** History, Philosophy and Concept, Principle Features, Strategies and domain based techniques, mechanism involved in the process intensification by fluid flow process, Mechanism of Intensification by mixing, Intensification in Reactive system.	**07L**
UNIT-02	**Process Intensification in Sustainable Development**: Problems leading to sustainable development, Concept, Issues and Challenges, Strategies in process design, design Techniques for Process Intensifications Scales and stages of process intensification, Methods and Tools for Achieving sustainable design, Multi-level Computer aided tools.	**06L**
UNIT-03	**Stochastic Optimization for Process Intensification:** Introduction on Stochastic Optimization, Optimization Algorithms, Applications of Optimization Algorithms, Process intensification by cavitation Introduction and Mechanism of Cavitation-based PI, Cavitational Reactor Configurations and activity, Parametric effects on cavitation.	**07L**
UNIT-04	**Process Intensification by Monolith Reactor:** Introduction of monolith reactor, Preparation of monolithic catalyst, Application of monolithic catalyst, Hydrodynamics, transport of monolithic reactor, Interfacial area based PI Overview of interfacial area based processes, Ejector induced downflow system for PI, Hydrodynamics and transport in downflow system.	**08L**
UNIT-05	**Process Intensification in Distillation:** Introduction and Principles, Types of Intensified Distillation Units, Design of membrane-assisted distillation, process intensification in extraction Introduction and Principles, Supercritical extraction for process intensification, micro-process technology in process intensification Introduction to microprocess technology, Process Intensification by Microreactors, Hydrodynamics and transport in microchannel based microreactor.	**05L**

Course Outcomes

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

CO1: Explain the concept of Process Intensification and the methodologies for PI.
CO2: Explain the benefits of PI in the process industries.
CO3: Explain the operating principles of a number of intensified technologies.
CO4: Analyze the range of potential applications of intensified equipment.
CO5: Design compact heat exchanger.

Books and References

1. Process Intensification: engineering for efficiency, sustainability and flexibility by D. A. Reay, C. Ramshaw, and A.P. Harvey, 2nd edition, (IChemE) Butterworth Harriman, London, 2008.
2. Re-Engineering the Chemical Processing Plant: Process Intensification by A. Stankiewicz, and J.A. Moulijn, (Eds.), CRC Press, 2003.
3. Process Intensification in Chemical Engineering Design Optimization and Control by J.G. Segovia-Hernandez, A. Bonilla-Petriciolet, (Eds), Springer, 2016.
4. Modelling of Process Intensification by F.J. Keil, (Ed.), Wiley International, 2007.
5. Process Design Synthesis, Intensification and Integration of Chemical Processes by H. Mothes, Manufective, 2015.
6. Chemical Engineering by J. M. Coulson, J. F. Richardson, Volume-1, Butterworth-Heinemann, 6th Edition, 1999.

Course Name: **Chemical Reactor Analysis and Design**
Course Code: **CH-462**
Course Type: **Stream Elective - I**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To provide the fundamentals of material and energy balances applicable to chemical reactor design for ideal reactors.
- To provide an understanding of rate laws and their derivation.
- To give detailed understanding in defining problems, analyzing data, and designing chemical processes.
- To provide a detailed overview for applying the concepts in heterogeneous catalysis, biological catalysis and non-ideal reactor schemes.

Unit Number	Course Content	Lectures
UNIT-01	**Review of Chemical Reaction Engineering:** Introduction to chemical reaction engineering, Review of design of ideal isothermal homogeneous reactors for single and multiple reactions	**06 L**
UNIT-02	**Residence time distribution (RTD):** RTD of ideal reactors, interpretation of RTD data, flow models for nonideal reactors – axial dispersion, N-tanks in series, and multiparameter models, diagnostics and troubleshooting, influence of RTD and micro-mixing on conversion	**06 L**
UNIT-03	**Reactor operation:** Adiabatic and non-adiabatic batch and flow reactors, optimal temperature progression, hot spot in tubular reactor, autothermal operation and steady state multiplicity in continuously stirred tank reactor (CSTR) and tubular reactors	**08 L**
UNIT-04	**Introduction to multiphase catalytic reactors:** Multiphase reactors**,** effectiveness factor, selectivity, catalyst deactivation, use of pseudo-homogeneous models for design of heterogeneous catalytic reactors (fixed and fluidized beds)	**10 L**
UNIT-05	**Gas-solid reactors:** Hydrodynamics and design of bubble column, slurry and trickle-bed reactors, introduction to laboratory reactors	**06 L**

Course Outcomes

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

CO1: Derive and apply material and energy balances required to design isothermal and non-isothermal catalytic reactors (PBR and FBR).

CO2: Solve problems of mass transfer with chemical reaction in heterogeneous catalysis process.

CO3: Solve problems of one-parameter non-ideal reactor modeling.

CO4: Analyze and solve problems of variable density and multiple independent reactions.

Books and References

1. Elements of Chemical Reaction Engineering by H.S. Fogler, 4th Edition, Pearson Education India, 2015.
2. Chemical Reactor Analysis and Design by G.F. Froment, K.B. Bischoff, and De Wilde, 3rd Edition, Wiley, 2010.
3. Chemical Reaction Engineering by O. Levenspiel, 3rd Edition, Wiley India, 2011.
4. Chemical Engineering Kinetics by J.M. Smith, 3rd Edition, McGraw Hill Education, 1981.

Course Name: **Water and Wastewater Treatment Technologies** Course Code: **CH-463** Course Type: **Stream Elective - I**		
Contact Hours/Week: **3L**		Course Credits: **03**
Course Objectives • To understand the science and technologies of wastewater treatment processes and operations.		
Unit Number	**Course Content**	**Lectures**
UNIT-01	**Wastewater Characteristics and Effluent Standards:** Physical, chemical and biological parameters of water pollution; DO, BOD and BOD kinetics; Nutrients; Effluent standards. **Overview of Wastewater Treatment Technologies:** Preliminary, primary, secondary and tertiary treatment technologies.	**06 L**
UNIT-02	**Preliminary Treatment:** Screens; Grit removal facilities; Effluent sumps and pumps; and Equalization tanks	**06 L**
UNIT-03	**Primary Treatment:** Neutralization and precipitation; Primary and secondary sedimentation tanks; Membrane filtration processes; Roughing filters.	**08 L**
UNIT-04	**Biological Treatment:** Activated sludge process and its modifications including SBR; Trickling filters and RBC units; SAF, FAB and MBBR technologies; UASB reactors and its modifications; Waste stabilization pond systems and its modifications.	**08 L**
UNIT-05	**Advanced Water Treatment Technologies:** Ion-exchange process; Adsorption process; membrane processes (nanofiltration and reverse osmosis); Defluoridation units and household level water purification systems, Advanced oxidation processes; Biological nutrient removal; Filtration and chlorination; Membrane processes for TDS reduction.	**08 L**
Course Outcomes Upon successful completion of the course, the student will be able to CO1: Decide on the scheme of treatment for wastewaters. CO2: Design, analysis, operate and control the routinely used biological wastewater treatment units. CO3: Monitor the wastewater treatment plants and characterize the wastewater samples. CO4: Decide on the facilities and provisions for the handling and management of the water and waste water treatment sludges.		
Books and References 1. Wastewater Engineering – Treatment, Disposal and Reuse by Metcalf, Eddy, G. Tchobanoglous, F.L. Burton, and H.D. Stensel, Tata McGraw Hill, 4th edition, 2002. 2. Industrial Water Pollution Control by WW Jr. Eckenfelder, McGraw Hill, 3rd edition, 2003. 3. Biological Wastewater Treatment, Edited Volume Series, IWA, 2008.		

Course Name: **Advanced Transport Phenomena**
Course Code: **CH-464**
Course Type: **Stream Elective - I**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To discuss the fundamentals of momentum, mass and energy balances as well as vector and tensor.
- To develop physical understanding of principles discussed and with emphasis on chemical engineering applications.
- To enable the students in advanced topics of transport phenomena fundamentals and applications to different Chemical Engineering applications.

Unit Number	Course Content	Lectures
UNIT-01	**Vector and Tensors:** Vector operations from a geometrical view point. Vector operation from an analytical view point, the vector differential operations, and second order tensors. Various vector and tensor identities.	**06 L**
UNIT-02	**Velocity Distributions in Laminar Flow:** Shell momentum balances: Flow of a falling film, flow through a circular tube, flow through an annulus. Non-Newtonian fluids. The Equations of Change for Isothermal Systems: Equation of continuity, the equation of motion, the equation of mechanical energy. Eulerian and Lagrangian formulation. Integral form of conservation equations, Reynolds Transport theorem.	**11 L**
UNIT-03	Solution of unsteady flow over a wall suddenly set in motion. Flow in porous and packed bed. Creeping around sphere and cylinder.	**02 L**
UNIT-04	**Temperature Distributions in solids and in Laminar Flow:** Heat conduction with an electrical heat source, heat conduction with nuclear heat source, entropy conservation, The Equations of change for Non isothermal systems: The equations of energy, the energy equation in curvilinear coordinates, the equations of motion for forced and free convection in nonisothermal flow, use of equation of change to set up steady and unsteady heat transfer problems, Solution of unsteady heat conduction equation.	**06 L**
UNIT-05	**Concentration Distributions in Solid and in Laminar Flow:** Velocities and mass fluxes, Fick's law of diffusion, Shell mass balances: diffusion into a falling liquid film, forced – convection mass transfer. Solution of unsteady diffusion problem.	**06 L**
UNIT-06	Analogies between momentum, heat and mass transfers, similitude and dimensional analysis. Interphase transport; Boundary Layer and Turbulence: Laminar boundary layer flow, heat and mass transfer. Time averaging of various conservation equations in turbulent flow, universal velocity distribution curve. Reynolds stresses and fluxes, various turbulent models.	**05 L**

Course Outcomes

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

CO1: Understand the concept of vectors and tensors.

CO2: Understand the mechanism of momentum, heat and mass transport for steady and unsteady flow.

CO3: Develop analogies among momentum, energy and mass transport.

CO4: Solve the governing equations to obtain velocity, temperature and concentration profiles.

Books and References

1. Transport Phenomena by R.B. Bird, W.E. Stewart and R.N. Lightfoot, John Wiley and Sons.
2. Fundamentals of Momentum, Heat and Mass Transfer by J.R. Welty, R.E. Wilson and C.E. Wicks, John Wiley and Sons.
3. Momentum, Energy and Mass Transfer in Continua by J.C. Slattery, McGraw Hill Co.

Course Name: **Bioprocess Engineering** Course Code: **CH-481** Course Type: **Stream Elective - II**		
Contact Hours/Week: **3L**		Course Credits: **03**
Course Objectives • To impart the knowledge about the fundamentals in bioprocess engineering. • To demonstrate the fundamentals of media design, sterilization, and downstream processing. • To enable the students to design and monitor the bioreactor.		
Unit Number	**Course Content**	**Lectures**
UNIT-01	**Introduction and Microbial Growth:** Introduction of Bioprocess, Cell theory, structure and classification of microorganism, Media Preparation, Media design and optimization, Sterilization, Batch and continuous heat sterilization, Microbial growth and kinetics in batch culture, Kinetics of thermal death of microorganisms, Heat Generation, microbial growth analysis by direct & indirect methods.	**08L**
UNIT-02	**Enzyme Technology:** Enzyme mechanism, kinetic model for enzymatic reaction, determination of kinetic parameters, enzyme inhibition, enzyme deactivation, immobilized enzyme kinetics: external and intra-particle mass transfer, immobilized enzyme reactor configurations, commercial production and applications.	**07 L**
UNIT-03	**Bioreactor Design and Operation:** Ideal & non-ideal bioreactors, modes of reactor operations, biomass growth, substrate uptake and product formation: mass & heat balances, structured and unstructured models, fermenter design & configuration: cell recycle reactors, air-lift, bubble column, perfusion, packed, plug-flow and fluidized bed reactors, mass & heat transfer in gassed reactor, solid-state fermentation.	**07 L**
UNIT-04	**Bioprocess Optimization, Control & Scale-up:** Conventional and statistical optimization of bioprocesses, Bioreactor control mechanism, PI, PD & PID control, cascade & digital control, computer control, biosensors, process scale-up criteria & correlations, pilot plant layout.	**06 L**
UNIT-05	**Downstream Processing and Product Recovery:** Protein Analysis, Concentration and Purification, Unit Operations: Filtration (micro, cross-flow and ultra) and centrifugation (high-speed, continuous and ultra), cell disruption methods, Precipitation, coagulation, flocculation, aqueous 2-phase extractions, dialysis, electro-dialysis, reverse osmosis, ultrafiltration, SDS-PAGE, Adsorption, Chromatography (HPLC, Column chromatography, gel filtration, ion exchange, affinity etc.), drying, crystallization, formulation, packaging, examples of complete commercial bioprocesses.	**08 L**
Course Outcomes Upon successful completion of the course, the student will be able to CO1: Measure extent of biochemical growth, types of biochemical interactions for living processes. CO2: Analyze the microbial growth and enzyme kinetics. CO3: Design of fermenter for bioprocessing of different products. CO4: Control, optimize and scale up the bioprocess. CO5: Apply downstream processing for separation and purification of bio-products		
Books and References 1. Bioprocess Engineering-Basic Concepts by M.L. Shuler and F. Kargi, Second Edition, Pearson, 2020. 2. Bioprocess Engineering Principles by P.M. Doran, Second Edition, Academic Press, 2012. 3. Biochemical Engineering Fundamentals by J.E. Bailey and D.F. Ollis, Second Edition, McGraw Hill Education, 2017. 4. Bioseparations Science and Engineering by R.G. Harrison, P.W. Todd, S.R. Rudge and D.P. Petrides, 2nd Eition., Oxford University Press, 2003. 5. Microbiology by M.J. Pelczar, E.C.S. Chan and N.R. Krieg, 5th Edition, McGraw Hill, New York.		

Course Name: **Analytical and Characterization Techniques**
Course Code: **CH-482**
Course Type: **Stream Elective - II**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart knowledge about the statistical methods used in analyzing the data from analytical instruments.
- To introduce the fundamentals of analytical instruments used in chemical industries.
- To enable the student to identify the suitability of a particular analytical method(s) based on its merits, demerits, and limitations and to interpret the output data in required form.

Unit Number	Course Content	Lectures
UNIT-01	**Introduction to Chemical Analysis:** Qualitative and Quantitative analysis, fundamental theory of solution reactions i.e. chemical equilibrium, buffer solutions, Error, accuracy, precision, significant figures, correlation, regression, analysis of variance, mean and standard deviation.	**09 L**
UNIT-02	**Spectroscopic Analysis:** Introduction, theory and principles of UV-Vis Spectroscopy, Atomic Absorption Spectroscopy, Atomic Emission Spectroscopy, Mass Spectroscopy, Nuclear Magnetic Response Spectroscopy, Infrared Spectroscopy, Raman Spectroscopy.	**07 L**
UNIT-03	**Chromatographic Analysis:** Preparative, analytical chromatography, theory, principles and methodology of Thin Layer Chromatography, Liquid Chromatography (normal phase versus reversed phase chromatography), ion exchange, gel permeation and Gas Chromatography.	**05 L**
UNIT-04	**Thermal Analysis:** Introduction, theory, principles and methodology of Thermo-gravimetric (TG), Differential Thermo-gravimetric (DTG), Derivative Thermal Analysis (DTA) and Differential Scanning Calorimetry (DSC).	**05 L**
UNIT-05	**Electrochemical Analysis:** Theory of electrochemical analysis, principles and methodology of Electro-gravimetric analysis, Coulometry, Potentionmetry, Voltammetry.	**05 L**
UNIT-06	**Morphology and Crystallography Analysis:** Introduction, theory, principles and methodology of X-ray diffraction (XRD), scanning electron microscope (SEM), Transmission electron microscopy (TEM), Atomic force microscopy (AFM).	**05 L**

Course Outcomes

Upon successful completion of the course, the student will be able to
CO1: Identify of the need of specific analytical method(s).
CO2: Describe and analyze the statistical methods.
CO3: Apply Principles of quantitative analysis used for aqueous and solid sample characterization.
CO4: Asses the specific technique employed for characterizing different solutes in water.

Books and References

1. Instrumental Methods of Analysis by H.H. Willard, L.L. Merritt, J.A. Dean and F.A. Settle, 7th Ed., CBS Publisher and Distributors, 1986.
2. Thermal methods of Analysis: Principles, Application and Problems by J. Haines, Blackie Academic and Professional, 1994.
3. Chromatographic Methods by A. Braithwaite and F.J. Smith, 5th Ed., Blackie Academic and Professional, London, 1996.
4. Principles of Instrumental Analysis, 6th Ed., Thomson Books, 2007.
5. Instrumental Methods of Chemical Analysis by G.R. Chatwal and S.K. Anand, 5th Edition, Himalaya Publishing House, 2005.

Course Name: **Introduction to Plastic Materials**
Course Code: **CH-483**
Course Type: **Stream Elective - II**

Contact Hours/Week: **3L** — Course Credits: **03**

Course Objectives

- To learn about the general methods of preparation of individual class of plastics Materials
- To study about the general properties, processing behavior and applications of different class of plastics materials
- To understand about the structure- property relation of different class of plastics materials.
- To familiar about properties and end application of different plastics materials
- To gain knowledge of thermoplastics for industrial applications

Unit Number	Course Content	Lectures
UNIT-01	**INTRODUCTION:** Basic chemistry of polymers-nomenclature of polymers sources for raw materials. Methods of manufacturing –properties and applications of Natural Polymers - Shellac resin and natural rubber, Cellulosics- Cellulose nitrate, cellulose acetate, cellulose acetate butyrate, Ethyl cellulose and others.	**05 L**
UNIT-02	**STRUCTURE OF PLASTICS:** Molecules - Crystallinity - Effect of Crystallinity on properties – crosslinked plastics, Determination of Molecular weight, Effect of Molecular weight on processing and properties, Molecular weight distribution. Linear, Branched and cross linked structures in polymers. Flexibility and movement of macromolecules. Glass transition temperature (Tg). Relationship.	**05 L**
UNIT-03	**COMMODITY THERMOPLASTICS & ITS APPLICATIONS:** Methods of manufacturing - general properties - processing behavior and applications of the following: Polyolefin - Polyethylene, LDPE, HDPE, LLDPE, HMHDPE, Polypropylene - Homo- polymers - Copolymers - Polytyrene & Styrene copolymers - Polystyrene, HIPS, ABS,Styrene - Acrylonitrile Vinyl plastics - Polyvinyl chloride, Polyvinyl Acetate, Polyvinylidene chloride, Polyvinyl alcohol & others.	**09 L**
UNIT-04	**ENGINEERING PLASTICS & ITS APPLICATIONS:** UHMHDPE -EPDM – EVA - Polyamides - Nylons 6, 66, 6 10, 11, 12 etc. Acrylic plastics - Polymethyl Methacrylate, Polyacrylonitrile - Polyesters - Polyethylene terephthalate, polybutylene terephthalate - Polycarbonate - Polyacetals.	**05 L**
UNIT-05	**HIGH PERFORMANCE PLASTICS:** Aromatic ether - Polypheneylene oxide, Aromatic thioether - Polyphenylene sulphide, Polysulfone, Polyimides – Polyimidazoles, Polyurethane, luoropolymers - Polyvinyl fluoride, Polyvinylidene fluoride, Polytetrafluoroethylene, Polychlorotrifluoroethylene.	**06 L**
UNIT-06	**THERMOSET MATERIALS & ITS APPLICATIONS:** Phenol formaldehyde - Urea formaldehyde - Melamine formaldehyde – Unsaturated polyesters, Alkyd resins - Epoxides - Polyurethane – Silicones - End use applications - case studies on applications – Moulding Powders.	**04 L**

Course Outcomes

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

CO1: Familiarize in natural polymer properties and its applications

CO2: Acquire skills in selecting additives for plastic materials for specific applications

CO3: Gain knowledge of manufacturing, properties and applications of poly olefins and vinyl halogenated olefin based plastic materials

CO4: Gain knowledge of manufacturing, properties and applications of special purpose plastics

Books and References

1. Plastics Materials by J. A. Brydson, Butterworth- Heinemann - Oxford, 7th Edition, 2001.
2. Plastics Materials and Processing by Schwartz & Goodman, 1982.
3. Synthetic Polymers by D. Feldman and A. Barbalata, Chapman Hall, 1996.
4. Handbook of Plastic Materials and Technology by Rubin Irvin I., Wiley India, 2014.

Course Name: **Petrochemical Engineering**
Course Code: **CH-484**
Course Type: **Stream Elective - II**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart knowledge about the statistical methods used in analyzing the data from analytical instruments.
- To introduce the fundamentals of analytical instruments used in chemical industries.
- To enable the student to identify the suitability of a particular analytical method(s) based on its merits, demerits, and limitations and to interpret the output data in required form.

Unit Number	Course Content	Lectures
UNIT-01	**Petrochemical Industry:** Indian Petrochemical Industry, Feedstocks, nature and effect of different types of refinery feedstock and impurities, refinery configuration and operation Process description and Process variables, Naphtha cracking, reforming, unit operations in petrochemicals industry.	**08 L**
UNIT-02	**Petrochemicals from Natural gas & Naphtha:** synthesis gas, hydrogen, acetylene, ethylene, propylene, butylene, aromatics and naphthenes, Methanol, Formaldehyde, Ethylene oxide, Ethylene Glycol, Isopropanol, Acetone, Butadiene, Maleic Anhydride, benzene, toluene, xylene.	**09 L**
UNIT-03	**Petrochemicals from Aromatics:** Cumene, Styrene, LAB, Bisphenol A, Terephthalic Acid, Phthalic Anhydride.	**06 L**
UNIT-04	**Polymer Based Industries:** Plastic, production of thermoplastic and thermosetting resins such as polyethylene: LDPE, LLDPE, HDPE, polypropylene, phenolic resins and epoxy resins, Polymers and their applications in engineering practice, Polyamides, polyesters and acrylics from monomers, Production of natural and synthetic rubbers, Nylon.	**08 L**
UNIT-05	**Offsite Facilities and Utilities:** Offsite facilities, layout of petrochemical plant, Off-gas treatment, effluent water treatment.	**05 L**

Course Outcomes

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

CO1: To describe the status of petrochemical industry in India together its present and future feed stocks and their production.

CO2: To identify various petrochemicals and their production techniques and associated challenges.

CO3: To know about various petrochemicals from aromatics and their separation.

CO4: To gain the knowledge of various thermosetting and thermoplastic value-added petrochemicals and learn their production techniques.

Books and References

1. Handbook of Petrochemicals Production Processes by R.A. Meyers, 2nd Edition, McGraw-Hill, 2019.
2. Petrochemical Process by A. Chawvel and G. Lefebvre, Vol. I & II, Gulf Publishing Co., Houston, London.
3. Petrochemical Process Technology by I.D. Mall, Macmillan India Limited, 2007.
4. Chemicals from Petroleum by A.L. Waddams, 4th edition, Gulf Publishing Company, London, 1980.
5. A Text on Petrochemicals by B.K.B. Rao, 2nd edition, Khanna Publishers, 1998.
6. Fundamentals of Petroleum and Petrochemical Engineering by U. Ray Chaudhuri, CRC Press, 2010.