Course Curriculum

(Course 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)

Second Year

3rd Semester							4th Semester						
SN	Code	Subject	L	T	P	Credits	SN	Code	Subject	L	T	P	Credits
1	HS-203	Organizational Behaviour	3	0	0	3	1	MA-203	Engineering Mathematics-III	3	1	0	4
2	CH-211	Fluid Mechanics	3	1	0	4	2	CH-221	Heat Transfer	3	1	0	4
3	CH-212	Chemical Engineering Thermodynamics-I	3	1	0	4	3	CH-222	Chemical Engineering Thermodynamics-II	3	1	0	4
4	CH-213	Chemical Process Calculations	3	1	0	4	4	CH-223	Industrial Pollution Abatement	3	1	0	4
5	CH-214	Mechanical Operation	3	1	0	4	5	CH-224	Chemical Technology	3	0	0	3
6	CH-215	Fluid Mechanics Lab	0	0	2	1	6	CH-225	Computational Lab	0	0	2	1
7	CH-216	Thermodynamics Lab	0	0	2	1	7	CH-226	Heat Transfer Lab	0	0	2	1
8	CH-217	Mechanical Operation Lab	0	0	2	1	8	CH-227	Chemical Technology Lab	0	0	2	1
		Total Hours = 25				**22**			**Total Hours = 25**				**22**

Third Year

5th Semester							6th Semester						
SN	Code	Subject	L	T	P	Credits	SN	Code	Subject	L	T	P	Credits
1	CH-311	Mass Transfer-I	3	1	0	4	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	1	0	4
3	CH-313	Process Equipment Design-I	3	0	0	3	3	CH-323	Process Equipment Design-II	3	1	0	4
4	CH-314	Process Dynamics and Control	3	1	0	4	4	CH-324	Process Modeling and Simulation	3	0	0	3
5	OET	Open Elective-I	3	0	0	3	5	OET	Open Elective-II	3	0	0	3
6	CH-315	Chemical Reaction Engineering Lab	0	0	2	1	6	CH-325	Mass Transfer Lab	0	0	2	1
7	CH-316	Process Dynamics and Control Lab	0	0	2	1	7	CH-326	Process Simulation Lab	0	0	2	1
8	CH-317	Industrial Pollution Abatement Lab	0	0	2	1	8	CH-327	Seminar	0	0	2	1
		Total Hours = 24				**21**			**Total Hours = 24**				**21**

Fourth Year													
7th Semester							8th Semester						
SN	**Code**	**Subject**	**L**	**T**	**P**	**Credits**	**SN**	**Code**	**Subject**	**L**	**T**	**P**	**Credits**
1	CH-411	Process Plant Design and Economics	3	0	0	3	1	HS-404	Engineering Economics and Accountancy	3	0	0	3
2	CH-412	Petroleum Refining and Petrochemical Engineering	3	0	0	3	2	CH-421	Industrial Safety and Hazard Management	3	0	0	3
3	DET	Professional Elective-I	3	0	0	3	3	DET	Professional Elective-III	3	0	0	3
4	DET	Professional Elective-II	3	0	0	3	4	DET	Professional Elective-IV	3	0	0	3
5	CH-413	Industrial Training Presentation	0	0	2	1	5	CH-422	General Proficiency	0	0	0	1
6	CH-414	Major Project (Stage–I)	0	0	12	6	6	CH-423	Major Project (Stage–II)	0	0	12	6
		Total Hours = 26				**19**			**Total Hours = 24**				**19**

Semester Wise Credits									
Semester	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**Total**
Credits	24	24	22	22	21	21	19	19	**172**
Hours/week	28	28	25	25	24	24	26	24	**204**

Professional Elective Courses

Professional Elective – I

CH-430	Optimization of Chemical Processes
CH-431	Computational Fluid Dynamics
CH-432	Instrumental Analytical Techniques
CH-433	Soft Computing Methods in Chemical Engineering

Professional Elective-II

CH-450	Fuel Cells and Hydrogen Energy
CH-451	Energy Engineering
CH-452	Solid Waste Management
CH-453	Reservoir Engineering

Professional Elective-III

CH-440	Biochemical Engineering
CH-441	Food Science and Engineering
CH-442	Fertilizer Technology
CH-443	Novel Separation Processes

Professional Elective-IV

CH-460	Polymer Science and Engineering
CH-461	Colloid and Interface Science
CH-462	Nanomaterials and Nanofabrication
CH-463	Heterogeneous Catalysis and Catalytic Processes

Open Elective Courses

Open Elective-I

CH-306	Energy and Environmental Engineering
CH-370	Nanoscience and Nanotechnology

Open Elective-II

CH-306	Energy and Environmental Engineering
CH-380	Industrial Safety and Hazard Management

Course Name: **Organizational Behaviour**
Course Code: **HS-203**
Course Type: **Core**

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

Course Objectives

- To impart knowledge about the behavioural aspects related to professional organizations
- To introduce the fundamental concepts relevant to understanding of individual & group behavior in the organization
- To enable the students to understand the applied organizational themes like perception, motivation, interpersonal relationships, group dhynamics, leadership theories, role of power & politices in organizational context, conflict and negotiation, organizational diversity, dynamics of personality, attitude and job satisfaction, etc.

Unit Number	Course Content	Lectures
UNIT-01	**Organizational Behavior (OB):** Concept, nature, characteristics, conceptual foundations, determinants and importance, management functions, role & skills, disciplines that contribute to the field of OB, Challenges & Opportunities for OB, diversity in Organizations, attitudes & Job satisfaction.	**04L**
UNIT-02	**Perception**: Concept, nature, process, importance, management and behavioral applications of perception. Personality: concept, nature, types and theories of personality shaping. Learning; concept and theories of learning.	**08L**
UNIT-03	**Motivation:** concept, principles, theories-content, process & contemporary, Monetary and non-monetary motivation, applications of motivation. Leadership: Concept, functions, styles, and theories of leadership- trait, behavioural, and situational.	**06L**
UNIT-04	**Group and Interpersonal Relationship:** Analysis of Interpersonal Relationship, developing interpersonal relationship, Group Dynamic: Definition of Group, stages of Group Development, Punctuated Equilibrium Model, Group Structure, Group Decision Making, understanding work teams.	**05L**
UNIT-05	**Organizational Power and Politics:** concept of power, structure of power, classification of power, contrasting leadership & power, dependence a key to power, causes & consequences of political behaviour. Organizational conflict: view of conflict, conflict process, negotiation & bargaining strategies.	**06L**
UNIT-06	**Conflict and Negotiation:** conflict definition in conflict thought: Traditional view, the Human relation view, interactionist view. Functional versus dysfunctional conflict, conflict process. Negotiation Bargaining strategies, the negotiation process and issues in negotiation.	**07L**

Course Outcomes

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

CO1: Identify the challenges of the present organization

CO2: Describe the organizational system

CO3: Apply the principles of organizational behavior to inculcate the habit of team work and which is essential for the organization

CO4: Assess the role of psychological and social principal in improvement of efficiency as well as quality of empoyee life

Books and References

1. Organizational Behavior by Robbins, S.P., Prentice Hall of India.
2. Organizational Behavior by Luthans F., McGraw-Hill.
3. Human Behavior at Work: Organizational Behavior by Davis K., Tata McGraw-Hill.

Course Name: **Fluid Mechanics**
Course Code: **CH-211**
Course Type: **Core**

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

Course Objectives

- To understand basic concepts of fluid flow 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, orificemeter, venturimeter, rotameter.	**11L**
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.	**08L**
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.	**07L**

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.
2. Fluid Mechanics and Fluid Power Engineering by D.S. Kumar, S. K. Kataria and Sons.
3. Fluid Mechanics by F.M. White, McGraw-Hill.
4. Fluid Mechanics: Fundamentals and Applications by J.M. Cimbala, and Y.A. Cengel, McGraw-Hill.
5. Hydraulics and Fluid Mechanics by P.N. Modi, and S.M. Seth, Delhi Standard Publishers.

Course Name: **Chemical Engineering Thermodynamics-I**
Course Code: **CH-212**
Course Type: **Core**

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

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 applications.

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.	**06L**
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.	**07L**
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.	**08L**
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.	**05L**
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.	**06L**
UNIT-06	**Power Cycles**: Rankine cycle, internal combustion engine cycles, gas-turbine power plant cycle.	**04L**

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-213**
Course Type: **Core**

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

Course Objectives

- To understand the basic units of different parameters used in various chemical process 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.
- To understand the fuels and combustion calculation, proximate and ultimate analysis.

Unit Number	Course Content	Lectures
UNIT-01	**Stoichiometry:** Units and dimensions, stochiometric 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, solubility and crystallization, dissolution, solubility of gases.	**06L**
UNIT-04	**Material Balance:** Material balances for systems with and without chemical reactions, species and elemental balance, analysis of systems with by-pass, recycle and purge.	**07L**
UNIT-05	**Energy Balance:** Steady state energy balance for systems with and without chemical reactions, heat capacity of gases, liquids and solutions, heat of fusion and vaporization, 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 student will be able to

CO1: Describe and solve material and energy balances simultaneously of a given process.

CO2: Calculate the bubble point and dew points of multicomponent mixtures.

CO3: Develop the skills to understand the use of psychrometric charts and determine the properties of air required in solving vaporization and condensation problems.

CO4: Illustrate the pressure-volume-temperature relation of ideal and real gases.

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-214**
Course Type: **Core**

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

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, Vol.-2, Butterworth-Heinemann, 2003.

Course Name: **Fluid Mechanics Lab**
Course Code: **CH-215**

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: **Thermodynamics Lab**
Course Code: **CH-216**

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 student 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 **t**hermal conductivity and thermal diffusivity**.**

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

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. To determinethe power consumption and study of agitation and mixing characteristic of a fluid.
2. To determinethe drag coefficient using falling ball method.
3. To determinethe collection efficiency of a cyclone separator.
4. To determinethe screening efficiency in a vibrating screen.
5. To determinethe cake and filter medium resistance of plate and frame filter press.
6. To determine the specific cake resistance in constant pressure vacuum filter.
7. To determinethe crushing efficiency of a roll crusher.
8. To determine the energy required for grinding and critical speed of ball mill.
9. To determinethe settling characteristics of a batch settler.
10. To determine the separation efficiency using trommel screen.
11. To study the screw conveyor for transport applications.

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: **Engineering Mathematics-III**
Course Code: **MA-203**
Course Type: **Core**

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

Course Objectives

- To introduce the fundamental concepts relevant to function of complex variable, numerical differentiation and integration and numerical solution of linear, non-linear and system of equations.
- To have the idea of evaluation of real integrals using complex variable.
- To understand the concept of approximating & interpolating polynomials and finding values of function at arbitrary point.
- To impart knowledge of various numerical technique to solve ODE.

Unit Number	Course Content	Lectures
UNIT-01	**Functions of Complex Variable** Applications of De Moivre's theorem, Exponential, Circular, Hyperbolic and Logarithmic functions of a complex variable, Inverse Hyperbolic functions, Real and imaginary parts of Circular and Hyperbolic functions, Summation of the series-'C+iS' method. Limit and derivative of complex functions, Cauchy-Riemann equations, Analytic functions and its applications, Complex integration, Cauchy's theorem, Cauchy's integral formula, Series of complex function, Taylor series, singularities and Laurent's series, Cauchy's residue theorem and its application for the evaluation of real definite integrals.	**12 L**
UNIT-02	**Interpolation** Least square curve fit and trigonometric approximations, Finite differences and difference operators, Newton's interpolation formulae, Gauss forward and backward formulae, Sterling and Bessel's formulae, Lagrange's interpolation.	**06L**
UNIT-03	**Numerical Integration** Integration by trapezoidal and Simpson's rules 1/3 and 3/8 rule, Romberg integration, and Gaussian quadrature rule, Numerical integration of function of two variables.	**05L**
UNIT-04	**Numerical Solution of Ordinary Differential Equations** Taylor series method, Picard's method, Euler's method, Modified Euler's method, Runge-Kutta method. Predictor corrector methods, Adam Bashforth and Milnes method, convergence criteria, Finite difference method.	**07L**
UNIT-05	**Numerical Solution of Linear and Non Linear Equations** Non Linear Equations: Bisection Method, RegulaFalsi Method, Newton-Raphson Method, Iteration method. Linear Equations: Jacobi and Gauss Seidel Iteration methods, Relaxation method.	**06 L**

Course Outcomes

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

CO1: Understand and analyze the concept of Numerical Solution of Linear and Non Linear Equations, Ordinary Differential Equations and Function of complex variable.

CO2: Identify an appropriate technique to solve the linear, non-linear equations, ordinary differential equations.

CO3: Formulate the problems on related topics and solve analytically.

CO4: Apply the concepts of linear, non-linear equations, differential equations and complex analysis in various engineering problems.

CO5: Demonstrate the concepts through examples and applications.

Books and References

1. Complex Variables and Applications by R.V. Churchill, J.W. Brown,and R.F. Verhey, McGraw Hill.
2. A First Course in Complex Analysis with Applications by D.G. Zill, and P.D. Shanahan, Jones and Bartlett.
3. Numerical Methods for Scientific and Engineering Computation by M.K. Jain, S.R.K. Iyenger, and R.K. Jain, New Age International Publishers, New Delhi.
4. Numerical Methods for Engineers and Scientists by J.D. Hoffman, 2nd edition, CRC Press.
5. Numerical Analysis Mathematics and Scientific Computing by D. Kincaid, and W. Cheney, 3rd edition, American Mathematical Society.

Course Name: **Heat Transfer**
Course Code: **CH-221**
Course Type**: 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 concept and applications of heat transfer by conduction, convection and radiation.	**02L**
UNIT-02	**Conduction:** Fourier law, thermal conductivity in gases, liquids and solids and their estimations, one dimensional heat conduction with and without heat generation through plane walls, cylindrical and spherical surfaces, composite layers, insulating materials: critical and optimum thickness, extended surfaces, fins and their practical applications, unsteady state heat transfer and lumped heat model.	**07L**
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, condensation of mixed and pure vapors, film wise and drop wise condensations, loading in condensers and calculation of condensers.	**09L**
UNIT-04	**Radiation:** Black and gray body concept, Kirchoff's law, Wein's displacement law, Stefan-Boltzmann law, radiation between surfaces, combined heat transfer.	**06L**
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, NTU and efficiency of heat exchangers.	**07L**
UNIT-06	**Evaporation:** Principle, types of evaporators: single and multiple effects, material and energy balance in evaporators, boiling point elevation, effect of liquid head, thermo compression.	**05L**

Course Outcomes

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

CO1: Identification of heat transfer mechanisms in fluids and solids.
CO2: Describe and analyze problems involving steady state and unsteady state heat transfer.
CO3: Apply Principles of heat transfer in designing of heat exchangers and evaporators.
CO4: Assess the performance of heat exchangers and evaporators by numerical problems.

Books and References

1. Heat Transfer by J.P. Holman, 9th edition, McGraw Hill.
2. Heat Transfer: A Practical Approach by Y.A. Cengel, 4th edition, McGraw Hill, New York.
3. Unit Operations in Chemical Engineering by W.L. McCabe, and J.C. Smith, McGraw Hill, New York.
4. Process Heat Transfer by D.Q. Kern, McGraw Hill, New York.

Course Name: **Chemical Engineering Thermodynamics-II**
Course Code: **CH-222**
Course Type: **Core**

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

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.	**06L**
UNIT-02	**Thermodynamics of Flow Processes:** Compressible fluids, incompressible fluids, pump, compressors and ejectors, working principle and efficiency of pumps, compressors and ejectors.	**05L**
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.	**08L**
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.	**10L**
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.	**07L**

Course Outcomes

Upon Successful completion of the course, the students will be able to
CO1**:** Relate and understand the various thermodynamic properties.
CO2**:** Describethe different criteria of equilibrium based on thermodynamics relations.
CO3**:** Apply principle of thermodynamics laws to determine the different equilibrium states.
CO4**:** Assess theimportance 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. 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, K.V. Narayanan, PHI, 2013.
5. Thermodynamics and an Introduction to Thermostatistics by H.B. Callen, John Wiley and Sons, 1985.

Course Name: **Industrial Pollution Abatement**
Course Code: **CH-223**
Course Type: **Core**

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

Course Objectives

- To understand the important issues about industrial pollution
- To impart the knowledge about the 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.	**06L**
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, different unit operations and unit processes involved in conversion of polluted water to potable standards.	**12L**
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, brief concepts of control of gaseous emissions by absorption, adsorption, chemical transformation and combustion.	**12L**
UNIT-04	**Solid Wastes:** Analysis and quantification of hazardous and non-hazardous wastes, treatment and disposal of solid wastes, land filling, leachate treatment, incineration.	**6L**

Course Outcomes

Upon successful completion of the course, the student 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.
CO5: Analyze the characteristics of solid waste and its handling & management.

Books and References

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

Course Name: **Chemical Technology**
Course Code: **CH-224**
Course Type: **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
	Study of the following chemical industries/processes involving process details, production trends, thermodynamic considerations, material and energy balances, flow sheets, engineering problems pertaining to materials of construction, waste regeneration/recycling and safety, environmental and energy.	
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.	**10L**
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.	**07L**
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.	**03L**
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.	**07L**
UNIT-05	**Acids:** Mining of sulphur and manufacture of sulphuric acid, hydrochloric acid, nitric acid.	**04L**
UNIT-06	**Ceramic Industries:** Types and manufacture of cement, lime, gypsum, manufacture of glasses and special glasses, refractories.	**05L**

Course Outcomes

Upon successful completion of the course, the student 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: **Computational Lab**
Course Code: **CH-225**

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

Course Objectives

- Teach to convert chemical engineering problem into numerical code.
- To give insights of computational tools such as MATLAB
- To solve chemical engineering problems numerically

List of Experiments

1. Introduction to programming with MATLAB 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, Gauss-Seidel etc.
5. Finding eigenvalues and eigenvectors.
6. Curve fitting and interpolation
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**:** Apply numerical techniques to solve various chemical engineering problems.
CO2**:** Solve PDEs through MATLAB.
CO3**:** Analyze two-and three dimensional models through computations.

Course Name: **Heat Transfer Lab**
Course Code: **CH-226**

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

Course Name: **Chemical Technology Lab**
Course Code: **CH-227**

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

Course Objectives

- To introduce the students some simple chemical preparations such as preparation of soaps, pigments, resins and dye.
- To teach chemical analysis and extraction techniques.

List of Experiments

1. To prepare and study the properties of soap
2. Estimation of CaO in a given cement solution
3. Preparation of Azo dye
4. Preparation of urea and phenol formaldehyde
5. Preparation of prussian blue and chrome yellow
6. Preparation of pigments (barium white, malchite green and chromium oxide green)
7. To prepare phenol formaldehyde resin (Bakelite)
8. Extraction of oil from any seed material using Soxhlet apparatus
9. Estimation of moisture content of a given sample by Dean and Stark apparatus.
10. Estimation of carbon residue of a given sample using Conradson apparatus.
11. Estimation of cloud and pour point of a given sample
12. Estimation of flash point, fire point, smoke point of oils
13. Determination of aniline point of a given oil sample.

Course Outcomes

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

CO1: Conduct experimental procedure for manufacture of soap, organic chemicals, dye, etc.

CO2: Handle different apparatus and learn the skill in using instruments for analysis.

Course Name: **Mass Transfer-I**
Course Code: **CH-311**
Course Type: **Core**

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

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	**Diffusion**: Classification of mass transfer operation, choice of separation methods,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 & Theories**: 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 and counter current processes, and concept of ideal stage and stage efficiencies, continuous contact equipment.	**06L**
UNIT-04	**Gas Absorption and Stripping**: 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:** Wet and dry bulb hygrometry, psychometric chart and its use, cooling towers: classification, construction, operation and calculation,	**04L**
UNIT-06	**Drying:** Equilibrium in drying, batch drying and rate of batch drying, time of drying, drying rate calculation, drying equipment.	**04L**

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

Books and References

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

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

Contact Hours/Week: **3L+ 1T** 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 analyze the kinetic data, and to estimate the kinetic parameters.

Unit Number	Course Content	Lectures
UNIT-01	**Introduction:** 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.	**07L**
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	**08L**
UNIT-03	**Design for Multiple Reactions:** Reactions in parallel and series in CSTR and plug flow reactor, conversion, yield and selectivity.	**05L**
UNIT-04	**Temperature and Pressure Effect:** General design procedure, optimum temperature progression, adiabatic operation, non-adiabatic operation, semi batch reactors	**05L**
UNIT-05	**Residence Time Distribution (RTD):** 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);	**05L**
UNIT-06	**Non-ideal Reactor Modeling Using RTD**: Zero parameter model: segregation model and maximum mixedness model, tanks in series model, dispersion model.	**06L**

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: Determine the mean residence time and standard deviation using the RTD data
CO6: Analyze the performance of non-ideal reactors using various models.

Books and References

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

Course Name: **Process Equipment Design-I**
Course Code: **CH-313**
Course Type: **Core**

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

Course Objectives

- To understand various process codes & 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 design calculations manually.

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.	**06L**
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.	**07L**
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	**06L**
UNIT-04	**Design of Supports:** Design of skirt, lug and saddle supports for vertical and horizontal vessels.	**06L**
UNIT-05	**Design of Thick-walled High-pressure Vessels**: Stresses in a thick cylinder, theories of elastic failure.	**06L**
UNIT-06	**Equipment Fabrication and Testing:** Design of welded joints, post weld treatment, inspection and non-destructive testing of equipment.	**05L**

Course Outcomes

Upon successful completion of the course, the student 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: **Process Dynamics and Control**
Course Code: **CH-314**
Course Type: **Core**

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

Course Objectives

- To analyze the system behavior for the design of various control schemes
- To impart the 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, first and second order systems, thermocouple, level tank, mixing tank, U-tube manometer. Interacting and non-interacting systems, distributed and lumped parameter systems, dead time.	**08L**
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:** Advanced control techniques; feed forward, feedback, cascade, ratio, Smith predictor and inverse response compensator, application to equipment; distillation columns, reactors.	**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.

Books and References

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

Course Name: **Chemical Reaction Engineering Lab**
Course Code: **CH-315**

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

Course Objectives

- To learn about the different types of reactors
- To learn about carrying out reaction in different types of reactors to verify theoretical principles
- To learn about the design of reactors
- To learn about the estimation of reaction kinetic parameters 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 spinning basket reactor
10. Study of a adiabatic batch reactor

Course Outcomes

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

CO1: Learn how to experimentally verify various theoretical principles
CO2: Visualize practical implementation of chemical engineering equipment
CO3: Develop experimental skill

Course Name: **Process Dynamics and Control Lab**
Course Code: **CH-316**

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. To study the response of thermometer
2. To study the dead weight pressure gauge
3. To study the control valve characteristics
4. To study the interacting and non-interacting systems
5. To study the temperature controller
6. To study the flow controller
7. To study the study of PI and IP converter
8. To study the level control trainer
9. To study the cascade control trainer
10. To study the pressure controller
11. To study the 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

Course Name: **Industrial Pollution Abatement Lab**
Course Code: **CH-317**

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

Course Objectives

- To characterize the wastewater sample.
- To monitor the air quality.

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 samples by Winkler method.
6. Determination of Biological Oxygen Demand (BOD) from a given waste water sample.
7. Determination of Sludge Volume Index (SVI) of a given waste water sample.
8. Determination of phosphorous in waste water sample.
9. Estimation of fluoride in a given sample.
10. Determination of nitrite and nitrate nitrogen in waste water sample.
11. Determination of ammonical and organic nitrogen in waste water sample.
12. High volume sampler to measure the air quality.

Course Outcomes

Upon successful completion of the course, the student 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.

Course Name: **Mass Transfer-II**
Course Code: **CH-321**
Course Type: **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:** Mass Transfer equilibria, Raoult's Law and Dalton's law. partial vaporization and partial condensation, relative volatility,differential distillation and flash distillation, steam distillation, McCabe–Thiele and Ponchon Savarit methods, Fenske, Underwood and Gilliland equations, total reflux, minimum and optimum reflux ratios, multiple feeds and side streams.	**11L**
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.	**07L**
UNIT-03	**Leaching**: Solid-liquid equilibria,single stage & multistage cross current, co-current and countercurrent leaching operations, supercritical fluid extraction, equipment for leaching.	**06L**
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.	**06L**
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.	**06L**

Course Outcomes

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

CO1: Familiar with the various types of mass transfer equilibrium.

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

CO3: Select solvent for extraction and leaching operations.

CO4: Solve related to adsorption and crystallization.

Books and References

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

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

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

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	**Solid Catalysts**: Determination of surface area, void volume and solid density, pore volume distribution.	**05L**
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.	**08L**
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).	**05L**
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: Determination of surface area and pore size of catalyst.
CO3: Determine the internal and overall effectiveness factors.
CO4: Understand the effect of velocity, particle size and fluid properties on rate of reactions controlled by mass transfer.
CO5: Design fixed bed reactors involving chemical reactions with mass transfer.
CO6: Analyze the fluid particle reactions using the models.

Books and References

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

Course Name: **Process Equipment Design-II**
Course Code: **CH-323**
Course Type: **Core**

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

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 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,	**07L**
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.	**05L**
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, mechanical design of standard vertical short tube evaporator.	**06L**
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, mechanical design of rotary dryer.	**06L**
UNIT-05	**Process Design of Mass Transfer Columns:** Effect of vapor flow conditions of tray design, column sizing approximation, detailed design of tray.	**06L**
UNIT-06	**Mechanical Design of Mass Transfer Columns:** Column construction and internals, different stresses (axial, circumferential and compressive) induced in column and its calculations.	**04L**

Course Outcomes

Upon successful completion of the course, the student 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.

Course Name: **Process Modeling and Simulation**
Course Code: **CH-324**
Course Type: **Core**

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

Course Objectives

- To provide necessary training for process synthesis using simulation tools.
- To understand knowledge of fundamental principles and basic laws of modeling and approach for modeling.
- To develop mathematical models of chemical engineering systems using fundamental conservation laws.

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).	**05L**
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.	**06L**
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, model for heat exchanger, gravity flow tank, single and multiple effect evaporator systems.	**11L**
UNIT-04	**Distributed Parameter Models:** Convective problems, laminar flow of Newtonian liquid in a pipe, diffusive problems, combined convective and diffusive problems	**06L**
UNIT-05	**Simulation:** Implementation of the models and numerical methods using MATLAB/Simulink, introduction and use of process simulation software (ASPEN) for flow sheet simulation. Simulation of models such as isothermal CSTR, non-isothermal CSTR, batch reactor, heat exchangers.	**08L**

Course Outcomes

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

CO1: Develop an understanding how the simulators work and mathematical model of chemical engineering systems from fundamental laws.

CO2: Write computer program to simulate the model.

Books and References

1. Process Modeling Simulation and Control for Chemical Engineers by W.L. Luyben, McGraw Hill, 2013.
2. Process Plant Simulation by B.V. Babu, Oxford University Press, 2004.
3. Introduction to Chemical Engineering Analysis by T.W.F. Russell, and M.M. Denn, Wiley, 1972.
4. Process Dynamics - Modelling, Analysis and Simulation by B.W. Bequette, PHI International, 2003.
5. Chemical Reactor Design for Process Plants by H.F. Rase, Vol.-2: Case Studies and Design Data, John Wiley, New York, 1997.

Course Name: **Mass Transfer Lab.**
Course Code: **CH-325**

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 in sieve plate distillation column.
2. Distillation in a packed bed 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. Determination of extraction coefficient for liquid-liquid extraction in a packed tower.
9. Determination of leaching coefficient solid -liquid extraction study in packed column.
10. To study the drying characteristics curve under constant drying condition in rotary vacuum or tray dryer.
11. To study and verify the Raleigh equation for batch distillation.
12. To determine the mass transfer coefficient for absorption in packed column
13. To study the humidification and dehumidification characteristics.
14. Estimation of flux and separation factor in membrane filtration (UF/NF)
15. To estimate the crystallization efficiency in batch crystallizer.

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: **Process Simulation Lab**
Course Code: **CH-326**

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

Course Objectives

- To introduce students to solve process simulation problems using MATLAB and ASPEN-Plus for Chemical Engineering problems

List of Experiments

1. Introduction and Stepwise Aspen Plus simulation: flash drum examples
2. Steady state and dynamic simulation of CSTR using ASPEN HYSYS.
3. Steady state and dynamic simulation of PFR using ASPEN HYSYS.
4. Steady state and dynamic simulation of multicomponent distillation column using ASPEN HYSYS
5. Simulation of chemical plant using ASPEN Plus
6. Dynamics and control using ASPEN dynamics
7. Solving ODE, linear and non-linear algebraic equations using MATLAB
8. SIMULNIK for solving chemical engineering and control problems
9. Modeling and simulation of shell and tube/plate type heat exchanger using programming language
10. Diffusion of species in the micro-fluidic devices
11. Basic CFD problems in ANSYS and/or COMSOL software

Course Outcomes

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

CO1: Run the computational software to solve physical problems

CO2: Learn industrial processes using software.

CO3: Correlations between experimental, numerical and theoretical results

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

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

Course Objectives

- To teach basic concepts of a chemical process and plant design.
- To understand concepts of economic balances and economic analysis of process plant.
- To familiarize with the commercial flowsheeting 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 hydrodealkylation of toluene (HDA) case study using ASPEN HYSYS/ ASPEN Plus®.	**04L**
UNIT-02	**General Plant Design Considerations:** Location, layout, site selection, general service facilities, different development stages starting from site selection till plant commissioning, environmental consideration, plant design of HDA case study.	**05L**
UNIT-03	**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 HDA case study.	**08L**
UNIT-04	**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.	**10L**
UNIT-05	**Heat Exchanger Networking:** 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.	**06L**
UNIT-06	**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.	**03L**

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 flowsheeting software to simulate chemical processes.

Books and References

1. Plant Design and Economics for Chemical Engineers by M.S. Peters, K.D. Timmerhaus, and 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.
6. 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: 2001).

Course Name: **Petroleum Refining and Petrochemical Engineering**
Course Code: **CH-412**
Course Type: **Core**

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

Course Objectives

- To impart knowledge about petroleum refineries and various operations carried out in it.
- To introduce the fundamental of various aspects of petrochemical engineering and petroleum products.
- To enable the student to work in a petroleum refinery as chemical engineering professional.

Unit Number	Course Content	Lectures
UNIT-01	**Introduction to Petroleum Industry:** Scope and purpose of refining; global and Indian refining scenario, practice and prospect. An overview of the entire spectrum of the refinery products, physiochemical characteristics of petroleum and petroleum products, refinery configuration development.	**06L**
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.	**08L**
UNIT-03	**Fuel Refining:** Cracking, coking, reforming, alkylation, isomerisation, polymerization, sweetening, visbreaking, hydroprocessing: hydro cracking, hydro treating, hydro finishing.	**09L**
UNIT-04	**Petrochemicals:**Refinery feedstock;nature and effect of different types of refinery feedstock and impurities on refinery configuration and operation, natural gas, production of petrochemical precursors - synthesis gas, hydrogen, acetylene, ethylene, propylene, butylene, aromatics and naphthenes, petrochemical derivatives and products.	**05L**
UNIT-05	**Polymer Based Industries and Their Characteristics:** Plastic; production of thermoplastic and thermosetting resins such as polyethylene, 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.	**05L**
UNIT-06	**Coal:** Gasification of coal and chemicals from coal.	**03L**

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: **Engineering Economics and Accountancy**
Course Code: **HS-404**
Course Type: **Core**

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

Course Objectives

- To impart knowledge about the Economics and its applicability to the Engineers
- To introduce the fundamental concepts of economics
- To enable the students to understand the factors that causes the changes in economic conditions of the entrepreneur

Unit Number	Course Content	Lectures
UNIT-01	**Introduction to Engineering Economics:** Definitions, Nature, Scope and application; Difference between Micro Economics and Macro Economics; Theory of Demand & Supply: Meaning, Determinants, Law of Demand, Elasticity of demand, Demand Forecasting, Law of Supply, Equilibrium between Demand & Supply.	**06L**
UNIT-02	**Production and Cost**: Production functions, Isoquant, Least Cost combination, Laws of Returns to Scale. Economics and Diseconomies of Scale of production, Cost and Cost curves, Revenue and Revenue curve, Break even analysis.	**06L**
UNIT-03	**Costing and Appraisal:** Cost elements, Economic cost, Accounting cost, Standard cost, Actual cost, Overhead cost, Cost control, Criteria of project appraisal, Social cost benefit analysis	**05L**
UNIT-04	**Markets**: Meaning, Types of Markets, Characteristics (Perfect Competition, Monopoly, Monopolistic Competition, Oligopoly) Price and Output Determination; Product Differentiation; Selling Costs; Excess Capacity.	**05L**
UNIT-05	**Money**: Meaning, Functions, Types; Monetary Policy- Meaning, Objectives, Tools; Fiscal Policy:-Meaning, Objectives, Tools. **Banking:** Meaning, Types, Functions, Central Bank: its Functions, concepts CRR, Bank Rate, Repo Rate, Reverse Repo Rate, SLR.	**04L**
UNIT-06	**Depeciation:** Meaning of depreciation, causes, object of providing depreciation, factors affecting depreciation, Methods of Depreciation: Straight line method, Diminishing balance method, Annuity method and Sinking Fund method	**04L**
UNIT-07	**Financial Accounting:** Double entry system (concept only), Rules of Double entry system, Journal(Sub-division of Journal) , Ledger, Trial Balance Preparation of final accounts-Trading Account. Profit and Loss account, Balance Sheet.	**06L**

Course Outcomes

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

CO1: Identify the challenges of the economy as entrepreneur/manufacturer as well as consumer
CO2: Describe the economic system at the micro and macro level
CO3: Apply principles of economics and accountancy in the professional, personal and societal life
CO4: Assess the role of engineering economics and accounting in attaining economic efficiency

Books and References

1. Principles of Micro Economics by Mceachern & Kaur, Cengage Publication.
2. Managerial Economics by Craig Peterson & W Cris Lewis, PHI Publication.
3. Modern Microeconomics by A. Koutsoyiannis, Macmillan.
4. Managerial Economics Theory and Applications by D. M.Mithani. Himalaya Publication House.
5. Fundamental of Managerial Economics Mark Hirschey, South Western Educational Publishing.
6. Engineering Economics by Degramo, Prentice Hall.
7. Financial Accounting–A Managerial Perspective by R. Narayanaswamy, PHI.
8. Introduction to Accounting by J.R. Edwards & Marriot, Sage Publication.
9. Cost Accounting by Jawahar Lal, Tata McGraw Hill.
10. Project Planning Analysis, Selection, Implementation and Review by Prasanna Chandra, Tata McGraw Hill

Course Name: **Industrial Safety and Hazard Management**
Course Code: **CH-421**
Course Type: **Core**

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	**06L**
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	**06L**
UNIT-03	**Industrial Hygiene:** Industrial hygiene anticipation and identification, industrial hygiene evaluation, hygiene control	**06L**
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	**08L**

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, 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: **Optimization of Chemical Processes**
Course Code: **CH-430**
Course Type: **Professional Elective-I**

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

Course Objectives

- To give basics of optimization problems.
- To discuss various linear and non-linear techniques.
- 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.	**04L**
UNIT-02	**Classical Optimization Techniques**: One dimensional minimization method**s:** Elimination methods- equally spaced points method, Fibonacci method and golden section method; Interpolation methods-quadratic interpolation and cubic interpolation, Newton and quasi-Newton methods.	**05L**
UNIT-03	**Linear Programming and Applications:** Basic concepts in linear programming, Graphical Solution, Simplex methods, Sensitivity analysis, Duality in linear programming, Transportation Problem	**06L**
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.	**12L**
UNIT-05	**Optimization of Staged and Discrete Processes:** Dynamic programming, Integer and mixed integer programming.	**03L**
UNIT-06	**Application of Optimization:** Heat transfer and energy conservation, Separation processes, Fluid flow systems, Chemical reactor design and operation	**06L**

Course Outcomes

Upon successful completion of the course, the student 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: **Computational Fluid Dynamics**
Course Code: **CH-431**
Course Type: **Professional Elective-I**

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, modeling versus experimentation.	**03L**
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, turbulence modeling.	**09L**
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.	**4L**
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 and transient heat conduction in rectangular and cylindrical geometries, convective heat transfer, solution of viscous incompressible flows by stream function-vorticity formulation solution of Navier-Stokes equation for incompressible flows using SIMPLE algorithm	**10L**
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, introduction to standard κ-ε model for turbulent incompressible flow	**10L**

Course Outcomes

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

CO1**:** Identify usefulness of CFD over experimentation and analytical approaches and basics of conservation principles
CO2: Find type of governing partial differential equation with physical description
CO3: Learn basic principles of finite difference method and its application in physical problems
CO4: Learn basic principles of finite volume method and its application in physical problems
CO5: Develop the power of numerical solution SOFTWARE to predict complex flows

Books and References

1. An Introduction to Computational Fluid Dynamics: The Finite Volume Method by H.K. Versteeg, and W. Malalasekera, Prentice-Hall Inc.
2. Computational Fluid Dynamics: The Basics with Applications by J.D. Anderson Jr., McGraw-Hill.
3. Computational Fluid Mechanics and Heat Transfer by D.A. Anderson, J.C. Tannehill., and R.H. Pletcher, Hemisphere Publishing Corporation.
4. Computational Fluid Dynamics by K.A. Hoffmann, and S.T. Chiang, Engineering Education System, USA.
5. Computational Fluid Flow and Heat Transfer by K. Muralidhar, and T. Sundararajan, Narosa Publishing House, New Delhi.

Course Name: **Instrumental Analytical Techniques**
Course Code: **CH-432**
Course Type: **Professional Elective-I**

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	**Instrumental Method of Chemical Analysis:** Classification, spectroscopy, electromagnetic spectrum, properties of electromagnetic radiation, types of molecular energies, interaction of electromagnetic radiation with matter, error, significant figure, precision, accuracy, methods of expressing accuracy, qualitative and quantitative analysis.	**06L**
UNIT-02	**Molecular Spectroscopy:** Photometer, spectrophotometer, colorimeter, deviation from Beer-Lambert law, types of transitions, theory, instrumentation, working principle, application and limitation: UV visible spectrophotometer, flame photometer, atomic absorption spectrophotometer, infrared spectroscopy, Raman spectrophotometer, nuclear magnetic resonance and mass spectroscopy.	**08L**
UNIT-03	**Morphology and Crystallography Analysis:** Theory, working principals, applications, advantages and limitations: X-ray diffraction (XRD), scanning electron microscope (SEM), transmission electron microscopy (TEM).	**08L**
UNIT-04	**Chromatography Techniques**: Chromatography, paper chromatography, thin layer chromatography, liquid-liquid partition chromatography, high performance liquid chromatography, ion exchange chromatography, gel chromatography and gas chromatography.	**08L**
UNIT-05	**Thermal Methods:** Introduction, instrumentation, advantage, application and limitation: thermal method of analysis, thermogravimetry (TG), differential thermo gravimetric (DTG), differential thermal analysis (DTA), differential scanning calorimeter (DSC).	**06L**

Course Outcomes

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

CO1: Identification 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. Principles of Instrumental Analysis by D.A. Skoog, F.J. Holler, and T.A. Nieman, 7th edition, Cengage Learning, 2018.
2. Instrumental Method of Chemical Analysis by G.R. Chatwal, and S.K. Anand, Himalaya Publishing House, 2005.
3. Instrumental Method of Analysis by H.H. Willard, L.L. Merritt, J.A. Dean, and F.A. Settle, 7th edition, Wadsworth Publishing Company, 1988.
4. Chromatographic Methods by A. Braithwaite, and F.J. Smith, 5th edition, Blackie Academic and Professional, London, 1996.

Course Name: **Soft Computing Methods in Chemical Engineering**
Course Code: **CH-433**
Course Type: **Professional Elective-I**

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

Course Objective

- To apply soft computing methods in various chemical process.

Unit Number	Course Content	Lectures
UNIT-01	**Artificial Intelligence (AI):** AI in chemical engineering, introduction to AI programming, introduction to prolog, introduction to AI principles, prolog, expert system for separation synthesis	**07L**
UNIT-02	**Artificial Neural Networks (ANN):** Introduction to 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	**Research Methodology:** 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	**Response Surface Methodology (RSM):** 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 student 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: Solve engineering problems using soft computational techniques.

CO3: 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. Design and Analysis of Experiments by D.C. Montgomery, John Wiley and Sons, 1984.
3. Computational Methods for Process Simulation by W.F. Ramirez, Butterworth Heinemann, 1998.
4. Applied Regression Analysis by N.R. Draper, and H. Smith, Vol-1, 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 Modeling in Chemical Engineering by R.G. Franks, Wiley Publications, 1967.

Course Name: **Fuel Cells and Hydrogen Energy**
Course Code: **CH-450**
Course Type: **Professional Elective-II**

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

Course Objectives

- To provide comprehensive and logical knowledge of hydrogen production, storage and utilization.
- To learn the fundamental knowledge about various fuel cell technologies.

Unit Number	Course Content	Lectures
UNIT-01	**Fuel Cells:** 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.	**08L**
UNIT-02	**Fuel Cell Characterization**: in-situ and ex-situ characterization techniques, I-V curve, frequency response analyses; Fuel cell system integration	**06L**
UNIT-03	**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-04	**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	**04L**
UNIT-05	**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.	**06L**
UNIT-06	**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.	**06L**

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.

Books 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: **Energy Engineering**
Course Code: **CH-451**
Course Type: **Professional Elective-II**

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

Course Objectives

- To emphasize on the role of energy, its consumption and future demand in modernization of the world
- To explain the importance of energy obtained from renewable and non-renewable resources
- To develop understanding on processing and handling the solid, liquid and gas fuels

Unit Number	Course Content	Lectures
UNIT-01	**Introduction:** Energy scene of supply and demand in India and the world, energy consumption in various sectors, potential of energy resources.	**02L**
UNIT-02	**Solid fuels:** Coal, origin, composition, classification of coal, properties of coal, proximate and ultimate analysis, classification of Indian coals, coal preparation, coal washing, storage of coal, carbonization, liquefaction and gasification, briquetting of coal, gasification and liquefaction of solid fuels	**06L**
UNIT-03	**Gaseous fuels:** Natural gas, hydrogen, methane from coal mines, producer gas, water gas, carburetted waster gas: lugri process, winkler process, koppers-totzek process, coal gas, blast furnace gas, gases from biomass, refinery gas and LPG	**06L**
UNIT-04	**Solar Energy:** Solar radiation and its measurement, limitations in the applications of solar energy, solar collectors: types, and constructional details. Solar water heating, applications of solar energy for heating, drying, space cooling, water desalination, solar concentrators, photovoltaic power generation using silicon cells.	**06L**
UNIT-05	**Bio-Fuels:** Importance, combustion, pyrolysis and other thermo chemical processes for biomass utilization. Alcoholic fermentation and anaerobic digestion for biogas production. **Wind Power:** Principle of energy from wind, windmill construction, operational details, electricity generation and mechanical power production.	**08L**
UNIT-06	**Tidal Power:** It's meaning, causes of tides and their energy potential, enhancement of tides, power generation from tides and problems. Principles of ocean thermal energy conversion (OTEC) analysis and sizing of heat exchangers for OTEC. **Geothermal Energy:** Geo technical wells and other resources dry rock and hot aquifer analysis, harnessing geothermal energy resources. Energy Storage and Distribution: Importance, biochemical, chemical, thermal, electric storage. Fuel cells, distribution of energy.	**08L**

Course Outcomes

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

CO1: Estimate the energy demand worldwide and available resources to overcome future demand

CO2: Understand about the conventional energy sources like solid and gaseous fuels

CO3: Understand about the non-conventional energy sources like solar energy, bio-fuels, wind power, tidal power and geothermal energy.

Books and References

1. Fuels and Combustion by S. Sarkar, Universities Press, 3rd edition, 2009.
2. Non-Conventional Energy Sources by G.D. Rai, Khanna Publishers, New Delhi, 2001.
3. Fuels- Solid, Liquid and Gaseous by J.S. Brame, and J.C. King, St. Martin Press.
4. Renewable Energy by B. Sorenson, 3rd edition, Elsevier Science, 2004.
5. Renewable Energy Resources by J. Twiddle, and T. Weir, Cambridge University Press, 1986.
6. Solar Energy: Principles of Thermal Collection & Storage by S.P. Sukhatme, 2nd edition, Tata McGraw-Hill, 2001.
7. Solar Energy: Fundamentals and Applications by H.P. Garg, and J. Prakash, Tata McGraw-Hill, 2001.

Course Name: **Solid Waste Management**
Course Code: **CH-452**
Course Type: **Professional Elective-II**

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

Course Objectives

- To facilitate understanding of issues and approaches associated with solid waste, hazardous waste and special category waste management.
- To enable the students to access legal requirements and strategies associated with management of municipal, hazardous and special solid waste.

Unit Number	Course Content	Lectures
UNIT-01	**Characterization and Quantification:** Solid waste management, nuisance potential and extent of solid waste problems, regulatory requirements, types and composition of solid waste, methods of quantification and characterization of wastes.	**08L**
UNIT-02	**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.	**06L**
UNIT-03	**Municipal Solid Waste Management:** Recycling, recovery of useful components of solid waste and its applications, composting, bio-gasification, waste to energy production.	**06L**
UNIT-04	**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.	**06L**
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.	**06L**
UNIT-06	**Special Category Wastes and Their Management:** Construction and demolition wastes, biomedical wastes, radioactive waste, e-waste, plastic waste, oil sludge and slurries.	**04L**

Course Outcomes

Upon successful completion of the course, the student 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 by A.D. Blude, and B.B. Sudaresan, INSDOC, 1972.
5. Integrated Solid Waste Management Engineering Principles and Management Issues, G. Tchobanoglous, H. Theisen, and S.A. Vigil, McGraw Hill, 1993.
6. Hazardous Waste Management by M.D. LaGrega, P.L. Buckingham, and J.C. Evans, Waveland Press, 2010.

Course Name: **Reservoir Engineering**
Course Code: **CH-453**
Course Type: **Professional Elective-II**

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	**06L**
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	**06L**
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	**08L**
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	**08L**
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	**08L**

Course Outcomes

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

CO1: To estimate the hydrocarbon quantity by oil and gas material balance equations
CO2: Acquire the knowledge on multiphase flow and flow of fluid in porous media
CO3: Visualize the complexities found in reservoir and various method available to enhance maximum cumulative oil recovery
CO4: Convert them into a successful reservoir engineer for oil and gas industry

Books and References

1. Fundamentals of Reservoir Engineering by L.P. Dake, Elsevier, 1983.
2. Enhanced Oil Recovery, D.W. Green, and G.P. Willhite, SPE Textbook Series, Vol. – 6, 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, 2006.

Course Name: **Biochemical Engineering**
Course Code: **CH-440**
Course Type: **Professional 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 to Bioscience:** 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 reactor analysis:** 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	**Transport processes in Bio reactors and its design:** Batch, fed-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, Food industry, Biological wastewater treatment.	**06L**

Course Outcomes

Upon successful completion of the course, the student 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 kinetics.
CO4: Design various bioreactors.

Books and References

1. Biochemical Engineering Fundamentals by J.E. Bailey, and D.F. Olis, McGraw-Hill, 1987.
2. Bioprocess Engineering by M.L. Schuler, and F. Kargi, Prentice Hall, 2002.
3. Bioprocess Engineering Principles by P.M. Doran, Academic Press, 2013.
4. Biochemical Engineering by M. Doble, and S.N. Gummadi, Prentice Hall, 2007.
5. Chemical Engineering by J.M. Coulson, and R.E. Richardson, Vol. - 3, Elsevier, 2014.

Course Name: **Food Science and Engineering**
Course Code: **CH-441**
Course Type: **Professional Elective-III**

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.

Books 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: **Fertilizer Technology**
Course Code: **CH-442**
Course Type: **Professional 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 occurring 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, classification of fertilizers, compound, complex and bulk blended fertilizers. N-P-K values and calculations.	**08L**
UNIT-02	**Nitrogenous Fertilizers**: Manufacturing processes for ammonia, effects of various factors on the process. Manufacture of ammonium sulphate, ammonium chloride, ammonium phosphate, ammonium nitrate, nitric acid, urea, etc. Economics and other strategies, material of construction and corrosion problem.	**10L**
UNIT-03	**Phosphatic Fertilizers:** Calculation of percentage tri-calcium phosphate of lime in phosphatic rock. Manufacture of single triple super phosphate. Nitrophosphate, sodium phosphate, phosphoric acid and other phosphatic fertilizers.	**10L**
UNIT-04	**Potash Fertilizers:** Manufacture of potash fertilizers like potassium sulphate, potassium chloride, etc.	**08L**

Course Outcomes

Upon successful completion of the course, the student 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. Commercial Fertilizers by G.H. Collings, 5th edition, McGraw Hill, New York, 1955.
2. Outlines of Chemical Technology by C.E. Dryden, East-West Press, New Delhi, 1973.
3. A Text Book of Chemical Technology by S.D. Shukla, and G.N. Pandey, Vol.-2, Vikas Publishing House, New Delhi.
4. Chemistry and Technology of Fertilizers by A.V. Slacks, Interscience, New York, 1966.

Course Name: **Novel Separation Processes**
Course Code: **CH-443**
Course Type: **Professional Elective-III**

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

Course Objectives

- To understand fundamentals of novel separation processes
- To study various membrane separation processes
- To study separation of biochemicals
- To understand basics of chromatography

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	**10L**
UNIT-02	**Surfactant Based Separation Processes:** Foam and bubble separation, principle, classification, foam and surfactants, separation techniques, column separations	**06L**
UNIT-03	**Centrifugal Separation Processes:** Principle, settling rates**,** sigma value and scale-up issue, separation of liquids	**05L**
UNIT-04	**Electrophoretic Separation Methods:** Forces in electrophoresis, factors influencing electrophoresis, gel membrane and paper electrophoresis, zonal electrophoresis	**05L**
UNIT-05	**Supercritical Fluid Extraction (SCF):** Critical conditions, supercritical solvents, parameters in SCF, basic technique.	**05L**
UNIT-06	**Ion Exchange and Chromatographic Separation Processes:** Principles and practice, classification of chromatographic techniques, gel filtration, ion exchange chromatography and chromato focusing, reversed phase and hydrophobic interaction chromatography, affinity chromatography	**05L**

Course Outcomes

Upon successful completion of the course, the student 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.

Textbooks:

1. Membrane Separation Processes by K. Nath, PHI, 2012.
2. Separation Process Principles by J.D. Seader, E.J. Henley, and D.K. Roper, John Wiley, 2015.
3. Transport Phenomena and Separation Process Principles by J. Genkoplis, PHI, 2015.
4. Separation Processes by C.J. King, McGraw Hill, 2013.
5. Water Purification by Ion Exchange by T.V. Arden, Springer, 1968.
6. Unit Operations of Chemical Engineering by W.L. McCabe, J.C. Smith, and P. Harriott, McGraw Hill, 2017.
7. Handbook of Separation Process Technology by R.W. Rousseau, Wiley-Blackwell, 1987.

Course Name: **Polymer Science and Engineering**
Course Code: **CH-460**
Course Type: **Professional Elective-IV**

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.	**09L**
UNIT-02	**Polymerization Processes:** Bulk, solution, emulsion and suspension polymerization, Comparison of polymerization processes.	**05L**
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.	**07L**
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.	**07L**
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.	**08L**

Course Outcomes

Upon successful completion of the course, the student 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: **Colloid and Interface Science**
Course Code: **CH-461**
Course Type: **Professional Elective-IV**

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

Course Objectives

- To familiarize with the knowledge about nano and micro scale interfacial phenomena.
- To provide fundamental concepts of difference between bulk and micro fluidics.
- To equip students with the knowledge of stability theory of thin film flows.

Unit Number	Course Content	Lectures
UNIT-01	**Fluid Interfaces and Capillarity:** Concepts of surface and interfacial energies and tensions, apolar (Van der Waals) and polar (acid-base) components of interfacial tension, Young-Laplace equation of capillarity, Kelvin equation, stability of equilibrium solutions, contact angle and Young's equation, thin liquid films.	**8L**
UNIT-02	**Thermodynamics of Interfacial Systems:** Thermodynamics concepts, capillary system, Gibb's treatment of interfaces, concept of excess concentration, variation of interfacial tensions with surfactant concentration, self-assembly of surfactants, insoluble monomers, adhesion, wetting, flotation.	**06L**
UNIT-03	**Electrical Phenomena at Interfaces:** Electrostatic double layer, zeta potential, acid-base interactions including hydrophobic attraction and hydration pressure, electrokinetics.	**6L**
UNIT-04	**Interaction Between Colloid Particles:** Long range van der Waals interactions, electrostatic interactions, DLVO theory, and kinetics of flocculation.	**8L**
UNIT-05	**Interfacial Hydrodynamics:** Unbalanced forces at fluid interfaces, Marangoni effect and its practical implications, effect of surfactants, Gibb's elasticity.	**8L**

Course Outcomes

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

CO1: Understand basic concepts and tools of colloid and interface science and engineering

CO2: Understand of differences between the surface and bulk dominated regimes and behavior and exploitation of nano-behavior.

CO3: Understand the stability concepts of micro-scale fluid flows.

Books and References

1. Principles of Colloid and Surface Chemistry by P.C. Hiemenz, and R. Rajagopalan, Marcel Dekker, New York, 1997.
2. An Introduction to Interfaces and Colloids: The Bridge to Nanoscience by J.C. Berg, World Scientific Singapore, 2010.
3. Intermolecular and Surface Forces by J. Israelachvili, Academic Press, New York, 1992.
4. Physical Chemistry of Surfaces by A.W. Adamson, and A.P. Gast, John Wiley & Sons, New York, 1997.

Course Name: **Nanomaterials and Nanofabrication**
Course Code: **CH-462**
Course Type: **Professional 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.	**06L**
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.	**07L**
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.	**06L**
UNIT-04	**Carbon Nanotubes:** Introduction to carbon nanotube, CNT from graphite, types of CNT, nanotubes and nano-wall structures, bucky onions nanotubes.	**05L**
UNIT-05	**Nanofabrication:** Nanolithography, photolithography, soft lithography, thin film deposition, etching and bonding, micro-electro-mechanical systems (MEMS), challenges & future development.	**05L**
UNIT-06	**Industrial Applications:** Solar energy conversion and catalysis, molecular electronics and printed electronics, liquid crystalline systems, applications in displays and other devices, advanced organic materials for data storage, photonics, plasmonics, chemical and biosensors, nanomedicine and nano-biotechnology, applications in drug delivery, coating, membrane based application, polymer and paints industry, food and agriculture Industry, cosmetics, water treatment.	**07L**

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: **Heterogeneous Catalysis and Catalytic Processes**
Course Code: **CH-463**
Course Type: **Professional Elective-IV**

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

Course Objectives

- To gain the knowledge of catalyst characteristics
- To impart the knowledge about mechanism of catalytic reactions
- To enable the students to design of catalytic reactors.

Unit Number	Course Content	Lectures
UNIT-01	**Catalysis:** Homogeneous and heterogeneous catalysts, classification of catalytic reactions and catalysts, commercial chemical catalysts, steps in catalytic reactions.	**04L**
UNIT-02	**Preparation and Properties of Catalysts:** Methods of catalyst preparation, physical properties of catalyst – surface area, pore volume, pore size distribution, solid density, particle density, bulk density, void volume, catalyst promoters and inhibitors, catalyst accelerators and poisons.	**08L**
UNIT-03	**Adsorption and Catalytic Reactions:** Adsorption isotherms, surface reaction, single site and dual site mechanism, desorption, catalyst deactivation, pore structure and surface area estimation and their significance.	**08L**
UNIT-04	**External Transport Processes:** Fluid particle mass and heat transfer, Mass transfer-limited reactions in packed beds, Non-isothermal behavior of packed-bed reactors, Staged packed bed reactors for approaching optimum temperature progression, Stable operating conditions in reactors and hot spot formation, Effect of external transport processes on selectivity under non-isothermal conditions.	**08L**
UNIT-05	**Diffusion and Reaction in Porous Catalysts:** Intra-pellet mass transfer and diffusion in cylindrical and spherical porous catalyst particles, Thiele modulus, Diffusion controlled and surface reaction controlled kinetics, Effectiveness factor for catalysts, Effects of heat transfer – temperature gradients across fluid-solid film and across catalyst pellet, Fluidized bed reactors, Three phase reactors – slurry and trickle bed reactors.	**06L**
UNIT-06	**Generalized Design:** Design of catalytic reactors under adiabatic and non-adiabatic conditions, Design of industrial fixed-bed, fluidized-bed and slurry reactors.	**04L**

Course Outcomes

Upon successful completion of the course, the student will be able to
CO1: Develop various catalytic reaction mechanisms.
CO2: Characterize a catalyst.
CO3: Assess the effects of external heat and mass transfer effects in heterogeneous catalysis.
CO4: Calculate the effectiveness of a porous catalyst.
CO5: Design different types of reactors for catalytic reactions.

Books and References

1. Chemical Engineering Kinetics by J.M. Smith, McGraw-Hill, 1981.
2. Elements of Chemical Reaction Engineering by H.S. Fogler, Prentice-Hall of India, 2009.
3. Chemical Reactor Theory: An Introduction by K.G. Denbigh, and J.C.R. Turner, Cambridge University Press, 1984.
4. Chemical and Catalytic Reaction Engineering by J.J. Carberry, McGraw-Hill, 2001.
5. Chemical Reaction Engineering by O. Levenspiel, John Wiley, 2006.

Course Name: **Energy and Environmental Engineering**
Course Code: **CH-306**
Course Type: **Open Elective-I / II**

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

Course Objectives

- To inculcate fundamental knowledge and understanding of the major energy conversion processes.
- To impart the knowledge about the resource requirement and their impacts on environment.

Unit Number	Course Content	Lectures
UNIT-01	**Introduction:** Interrelationship between energy and environment, the need of sustainability, nature & issues; environment conservation and management as the key requirements of sustainability, scope and importance, need for public awareness, energy chain and common forms of usable energy, classification of energy sources, present energy scenario, world energy status, energy scenario in India.	**08L**
UNIT-02	**Conventional Energy:** Environmental impacts related to harnessing to fossil fuels (coal, oil, natural gas), nuclear energy, hydropower (overview of micro mini and small hydro power, classification of hydropower schemes), impact of energy production on climate change.	**06L**
UNIT-03	**Renewable Sources of Energy:** Solar energy; active and passive systems, measurement and applications including solar water heating, solar cooking, solar drying, solar distillation and solar refrigeration, heating and cooling of buildings, solar thermal power generation, solar photo-voltaic power generation, process economics and environmental impacts, biomass energy; generation, characterization, biogas (aerobic and anaerobic bio-conversion processes), properties of biogas, waste to energy (domestic sewage, municipal solid wastes); biorefineries, biohydrogen production, environmental aspects of biofuel utilization - techno-economic features of bio-fuels, wind energy, wind diesel hybrid systems, control of hybrid power systems, power generation through OTEC systems - various types - energy through waves and tides - energy generation through geothermal systems – types.	**14L**
UNIT-04	**Social Issues and the Environment:** Environmental degradation, environment ethics, issues and possible solutions, urban problems related to energy, water conservation, rain water harvesting, water shed management.	**08L**

Course Outcomes

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

CO1: Describe basic energy concepts.

CO2: Analyze the consequences of today's energy consumption.

CO3: Account for conventional energy technologies and the relationship between energy production, consumption and climate change.

CO4: Reflect and evaluate the environmental impact of energy production through renewable sources of energy.

Books and References

1. Energy and the Environment by R.A. Ristinen, and J.J. Kraushaar, 2nd edition, 1998.
2. Fundamentals of Renewable Energy Sources by G.N. Tiwari, and M.K. Ghosal, Narosa Publishing House, New Delhi, 2007.
3. Energy Technology by S. Rao, and B.B. Parulekar, 4th edition, Khanna Publishers, 2005.
4. Energy Science: Principles, Technologies and Impacts by J. Andrews, and N. Jelley, Oxford Universities Press, 2013.
5. Renewable Energy, Power for a Sustainable Future by G. Boyle, Oxford University Press, 2012.
6. Renewable Energy Systems, Advanced Conversion Technologies and Applications by L.Y. Fang, and Y. Hong, CRC Press, 2012.

Course Name**: Nanoscience and Nanotechnology**
Course Code**: CH-370**
Course Type**: Open Elective-I**

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

Course Objectives

- To impart knowledge about the basic concepts of nanoscience 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	**Nanoscience:** Introduction and importance, definition of nano, atomic structure and size, emergence and challenges of nanoscience, formation of CNT to Graphene, influence of nano over micro and macro, size effects, surface effects on the properties.	**06L**
UNIT-02	**Nanostructure and Nanomaterials Properties:** Types of nanostructure and properties of nanomaterials, one dimensional, two dimensional and three dimensional nanostructured materials, quantum dots shell structures, semiconductors, composites, mechanical-physical-chemical properties.	**07L**
UNIT-03	**Nanotechnology:** Introduction, emergence and challenges of nanotechnology, synthesis, vapor condensation methods, sputtering, laser method, spray pyrolysis, thermo chemical, flame decomposition of metals, organic precursors methods.	**05L**
UNIT-04	**Characterization Tools:** X-Ray diffraction (XRD), Scanning electron microscopy, transmission electron microscopy, atomic force microscopy, UV spectroscopy.	**06L**
UNIT-05	**Classification and Fabrication:** Introduction and classification, electronic properties of atoms and solids, nanometer length scale effects, fabrication methods; top down and bottom up fabrication approach, self-assembly, bio-mediated assembly, safety and storage issues.	**07L**
UNIT-06	**Industrial Applications:** Coating, **c**osmetics, nano sensor, nano catalysts, water treatment, paints industry, food and agriculture Industry, biological and environmental applications.	**05L**

Course Outcomes

Upon Successful completion of the course, the students will be able to
CO1: Identify and understand the peculiar properties of nano-materials at nanoscale.
CO2: Describe the chemistry involved in the synthesis and fabrication of nanomaterials.
CO3: Apply principle of nanoscience and 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, 200.

Course Name: **Industrial Safety and Hazard Management**
Course Code: **CH-380**
Course Type: **Open Elective-II**

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

Course Objectives

- To impart knowledge about various aspects of industrial safety and occupational health.
- To enable the students to identify hazard and assess risk.
- To teach about various safety acts and rules along with safety education and training.

Unit Number	Course Content	Lectures
UNIT-01	**Concepts and Techniques:** History of safety movement –Evolution of modern safety concept - Incident Recall Technique (IRT), disaster control, safety analysis, safety survey, safety inspection, safety sampling. Safety Audits-components of safety audit, types of audit, audit methodology, non-conformity reporting (NCR), audit checklist- identification of unsafe acts of workers and unsafe conditions in the industry.	**08L**
UNIT-02	**Occupational Health and Toxicology:** Concept and spectrum of health, functional units and activities of occupational health services, occupational related diseases and levels of prevention of diseases. Toxicology- local, systemic and chronic effects, temporary and cumulative effects, carcinogens entry into human systems.	**08L**
UNIT-03	**Hazard Identification and Risk Assessment:** The process of risk management, hazard identification, evaluation (risk assessment, risk matrix), risk control implementation, action and recommendation.	**06L**
UNIT-04	**Acts and Rules:** Indian boiler Act 1923, static and mobile pressure vessel rules (SMPV), motor vehicle rules, mines act 1952, workman compensation act, rules–electricity act and rules–hazardous wastes (management and handling) rules, 1989, with amendments in 2000- the building and other construction workers act 1996., Petroleum rules, Explosives Act 1983-Pesticides Act, Factories Act 1948, Air Act 1981 and Water Act 1974.	**07L**
UNIT-05	**Safety Education and Training:** Importance of training-identification of training needs-training methods – programmes, seminars, conferences, competitions – method of promoting safe practice - motivation – communication - role of government agencies and private consulting agencies in safety training – creating awareness, awards, celebrations, safety posters, safety displays, safety pledge, safety incentive scheme, safety campaign – domestic Safety and Training.	**07L**

Course Outcomes

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

CO1: Identify the key aspects of industrial safety and mitigating them
CO2: Describe various types of solution to problems arising in safety operations and hygiene.
CO3: Apply principles of OSHA in controlling industrial disasters and losses
CO4: Assess the overall performance of safety protocols of chemical industries and hazard management.

Books and References

1. Industrial Accident Prevention by H.W. Heinrich, McGraw-Hill, 1980.
2. Safety Management in Industry by N.V. Krishnan, Jaico Publishing House, Bombay, 1997.
3. Loss Prevention in Process Industries by F.P. Lees, Butterworth, London, 1990.
4. Safety at Work by J.R. Ridley, Butterworth, London, 1983.
5. Chemical Process Safety Fundamentals with Applications by D.A. Crowl, and J.F. Louvar, Prentice Hall, 2002.