Ref: UPL University /SRICT/BOS/CH/2022-23/01 **Date:** 28-01-2023

Teaching Scheme for Third Year Bachelor of Chemical Engineering

Semester-V (Chemical Engineering) Structure

Sl. No	Category of Course	Code No.	Course Title	Hours per week			Total contact hrs./ week	Total Credits	E	M	I	V	Total Marks
				L	T	P							
1	Humanities and Social Sciences including Management courses	CH2301	Plant Economics and Management	3	0	0	3	3	70	30	0	0	100
2	Professional Core Course-VII	CH2302	Mass Transfer Operations -I	3	0	2	5	4	70	30	20	30	150
3	Professional Core Course-VIII	CH2303	Chemical Reaction Engineering-I	3	0	2	5	4	70	30	20	30	150
4	Professional Core Course-IX	CH2304	Process Dynamics and Control	3	0	2	5	4	70	30	20	30	150
5	Professional Elective -II	CH2305/06/07	Professional Elective-II	3	0	0	3	3	70	30	0	0	100
6	Open Elective-II	CH2308/09	Open Elective-II	3	0	0	3	3	70	30	0	0	100
7	Mandatory Course	MH2301	Contributor Personality Development Program-I	1	1	0	2	2	50	30	20	0	100
8	Project work, seminar and internship in industry or elsewhere	MH2303	In Plant Training	0	0	2	2	1	0	0	50	00	50
	Total						**28**	**24**					**900**

Semester-VI (Chemical Engineering) Structure

Sl. No	Category of Course	Code No.	Course Title	Hours per week			Total contact hrs./ week	Total Credits	E	M	I	V	Total Marks
				L	T	P							
1	Professional Core Course-X	CH2310	Mass Transfer Operations -II	3	0	2	5	4	70	30	20	30	150
2	Professional Core Course-XI	CH2311	Chemical Reaction Engineering-II	3	0	2	5	4	70	30	20	30	150
3	Professional Elective -III	CH2312/13/14	Professional Elective - III	3	0	2	5	4	70	30	20	30	150
4	Professional Elective -IV	CH2315/16	Professional Elective - IV	3	0	0	3	3	70	30	0	0	100
5	Open Elective-III	CH2317/18	Open Elective-III	3	0	2	5	4	70	30	20	30	150
6	Open Elective-IV	CH2319/20	Open Elective-IV	3	0	0	3	3	70	30	0	0	100
7	Mandatory Course	MH2302	Contributor Personality Development Program-II	1	1	0	2	2	50	30	20	0	100
	Total						**28**	**24**					**900**

A. Course Code and Definition:

Abbreviations	Definitions
L	Lecture
T	Tutorial
P	Practical
E	Theory External Examination Marks
M	Theory Internal Examination Marks
I	Practical Internal Examination Marks
V	Practical External Examination Marks

B. List of Professional and Open Electives Courses Sem-V and VI

BE Sem -V			
Sr. No.	**Category of Course**	**Code No.**	**Course Title**
1.	Professional Elective -II	CH2305	Material Science and Engineering
2.		CH2306	Polymer Science and Technology
3.		CH2307	Membrane Technology (NPTEL Course)
4.	Open Elective-II	CH2308	Fuel Cell Technology
5.		CH2309	Fuel and Combustion

BE Sem -VI			
Sr. No.	**Category of Course**	**Code No.**	**Course Title**
1.	Professional Elective -III	CH2312	Petroleum Refining and Petrochemicals
2.		CH2313	Multicomponent Distillation
3.		CH2314	Biomass Conversion and Biorefinery (NPTEL Course)
4.	Professional Elective -IV	CH2315	Process Safety Management
5.		CH2316	Safety and Hazard Management
6.	Open Elective-III	CH2317	Waste to Energy
7.		CH2318	Process Utilities
8.	Open Elective-IV	CH2319	Nanoscience & Technology
9.		CH2320	Sustainable Technology

Bachelor of Engineering
Subject Code: CH2301
Subject Name: Plant Economics and Management

Shroff S.R. Rotary Institute of Chemical Technology

Semester: V

Type of course: Humanities and Social Science including Management Course

Prerequisite: Basic understanding of process equipment, chemical technology, knowledge of basic engineering mathematics.

Rationale: This course brings together the concepts of engineering and economics with special reference to chemical process and plant design along with the hierarchy of decisions in synthesis and analysis of a chemical process and its alternatives. This course is intended to challenge chemical engineer to combine basic technical principles learned in other courses in the general curriculum with practical elements of economics, business practices and organization along with principles of safety, environmental and sociological issues to design an integrated chemical process plant.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	0	3	70	30	00	00	100

Sr. No	Content	Total Hrs.
	SECTION-A	
1.	**Introduction:** Process development, importance of pilot plant, synthesis of process flow sheet, process flow diagrams.	**4**
2.	**Process Creation:** Techno economics feasibility analysis, factors affecting process selection, equipment specifications, plant location, plant layout, principles of plant layout.	**7**
3.	**Process Auxiliaries and Utilities:** Piping layout, and supports for piping insulations, pipe fittings, types of valves, optimum economic pipe diameter, selection of pumps, process water, boiler feed water, water treatment, steam, oil heating system, compressed air and vacuum.	**7**
	SECTION-B	
4.	**Cost Estimation:** Types of cash flow, factors affecting estimation of investment and production cost, breakeven point and its significance, total capital investment and its estimations, cost index, type of cost estimates, methods of cost estimation, capitalized cost, annuity, estimation of total product cost, contingencies, time value of money, nominal and effective interest rates.	**7**

5.	**Depreciation:** Types of depreciation, method for determining depreciation: straight line method, decline balance method, sum of the year digit method, shrinking fund method. **Profitability, Alternative Investments and Replacement:** methods of profitability evaluation, % rate of return, practical factors in alternative investment and replacement studies.	**7**
6.	**Project Management:** Production management, project planning & scheduling, BAR chart, CPM, PERT, comparison between CPM and PERT.	**4**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
20	25	25	10	20	0

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Textbooks:

1. Max S. Peters, K.D. Timmerhaus and R.E. West, Plant Design and Economics for Chemical Engineers, McGraw-Hill International Edition, Chemical Engineering Series, New York, USA, 2003.

Reference Books:

1. James M. Douglas, Conceptual Design of Chemical Processes, McGraw-Hill International Editions, Chemical Engineering Series, New York, USA, 1988.
2. Biegler L.T., I. E. Grossmann and A.W. Westerberg, Systematic Methods of Chemical Process Design, Prentice Hall, 1997.
3. Smith R., Chemical Process: Design and Integration, John Wiley and Sons, 2005.
4. V. V. Mahajani, Chemical Project Economics, Macmillan Indian Ltd., New Delhi, 2005.

Course Outcomes:

After learning this course, students will be able to:

Sr. No.	**CO statement**
CO-1	State the basic concepts of plant design & construct flow sheet.
CO-2	Describe the principles of process creation and selection.
CO-3	Classify small plant auxiliaries& process utilities.
CO-4	Execute the capital investment & cost estimation.
CO-5	Explain profitability and alternate investments.

CO-6	Define project planning and scheduling.

List of Open Source Software/learning website:

- https://nptel.ac.in/courses/

Bachelor of Engineering
Subject Code: CH2302
Subject Name: Mass Transfer Operations -I

Shroff S.R. Rotary Institute of Chemical Technology

Semester: V

Type of course: Professional Core Course-VII

Prerequisite: Basics of fluid dynamics and heat transfer

Rationale: The objective of this course is to study the principles of mass transfer and their applications to separation and purification processes in chemical industry. This course is intended to explain detailed fundamentals of mass transfer operations such as diffusion, mass transfer coefficient, inter phase mass transfer etc. and its application for in depth study and for solving problems pertaining to some mass transfer operations such as in detail. This course also enables the students to understand principal and working of various mass transfer equipment like gas absorption columns, crystallizers, and extractors etc.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	4	70	30	30	20	150

Sr. No	Content	Total Hrs.
	SECTION-A	
1.	**Introduction:** Definition and aim of mass transfer operations, classification of mass transfer operation with examples, direct vs indirect mass transfer operations, choice of separation method, methods of conducting mass transfer operations, design principles. **Molecular Diffusion in Fluids:** Definition of molecular and eddy diffusion, Fick's law, concept of N & J flux, steady state molecular diffusion in fluids at rest and in laminar flow, concept of effective diffusivity, diffusivity of gases, diffusivity of liquids.	**6**
2.	**Mass Transfer Coefficients:** Mass transfer in laminar and turbulent regions, F and K type mass transfer coefficients, film, penetration and surface renewal theories, analogies between momentum, heat and mass transfer, dimensionless numbers. **Inter Phase Mass Transfer:** Concept of equilibrium, diffusion between phases, two resistance theory, local overall mass transfer coefficient, controlling mass transfer resistances.	**7**
3.	**Equipment for Gas Liquid Operations:** Gas dispersion, sparged vessels, mechanically agitated vessels, gas-liquid contact, tray tower, tray tower internals, different types of trays, weirs, down comer and criteria of their selection, flooding,	**5**

	loading, coning, weeping & dumping in tray tower. **Liquid Dispersed:** Venturi scrubber, wetted wall towers, spray towers, packed towers, packed tower internals, different types of packing and their selection criteria, mass transfer coefficient for packed towers, co-current flow of gas & liquid, end effects and axial mixing, tray tower vs. packed tower.	
SECTION-B		
4.	**Liquid-Liquid Extraction:** Ternary liquid- liquid equilibrium and tie line data, system of three liquids-one pair partially soluble, two partially soluble, two partially soluble liquids and one solid, multi-component system, stage wise contact, single stage & multistage extraction, co-current and cross current extraction, continuous counter current multistage extraction with and without reflux, theory & performance of continuous contact equipment, single stage & multistage equipment, applications of liquid-liquid extraction.	**8**
5.	**Leaching:** Steady state and unsteady state leaching operations, single stage leaching, multistage cross current and counter current leaching, rate of leaching, recovery of solvent vapors, application of leaching, leaching equipment.	**6**
6.	**Crystallization:** Saturation, nucleation, principle of crystallization, crystallization rate, equilibria and yields, nucleation, crystal growth, caking of crystals, application of crystallization, crystallization equipment.	**4**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
25	50	10	15	-	-

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Textbooks:

1. R. E. Treybal, Mass Transfer Operations, 3rd edition, Mc-Graw Hill International, 1983.

Reference Books:

1. Binay K. Dutta, Principles of Mass Transfer and Separation Processes, 2nd edition, Prentice Hall of India, 2007.
2. J. F. Richardson, J. H. Harkar, Coulson and Richardson's Chemical Engineering, Volume-2, 5th edition, Butterworth Heinemann, 2002.
2. W. L. McCabe, J. C. Smith & Harriott, Unit Operations of Chemical Engineering, 6th edition Mc-Graw Hill International, 2001.
3. C. J. Geankoplis, Transport Processes & Unit Operations, 3rd edition, Prentice Hall of India, 1993.

Bachelor of Engineering
Subject Code: CH2302
Subject Name: Mass Transfer Operations -I

Shroff S.R. Rotary Institute of Chemical Technology

List of Practicals:

Sr. No.	Practicals	Approx. Hours required
1.	To determine the diffusion co-efficient of CCl_4 in air & it's variation with temperature.	2
2.	To determine the mass transfer co-efficient for diffusion of acetone.	2
3.	To determine the % extraction for the benzoic acid from dilute aqueous solution using toluene as solvent.	2
4.	To study multistage (cross current) liquid-liquid extraction for extracting acetic acid from benzene using water as solvent.	2
5.	To find out crystal yield with & without seeding	2
6.	Mass transfer with chemical reaction	2
7.	Mass transfer without chemical reaction	2
8.	Leaching of salt from salt and sand mixture	2
9.	Evaluation of extraction % by CHEMCAD for benzoic acid and toluene.	2
10.	Evaluation of multi stage extraction by CHEMCAD	2

Course Outcomes:

After learning this course, students will be able to:

Sr. No.	CO statement
CO-1	Describe fundamentals of diffusion; inter phase mass transfer and mass transfer coefficients.
CO-2	Explain various mass transfer operations and their equipment used in chemical industries.
CO-3	Apply theoretical and analytical aspects of mass transfer operations to deal with complex problems of separations.
CO-4	Solve problems pertaining to gas absorption.
CO-5	Classify different liquid-liquid extraction operations.
CO-6	Evaluate the material balance for crystallization and leaching.

List of Open Source Software/learning website:

- https://archive.nptel.ac.in/courses/103/103/103103145/

Bachelor of Engineering
Subject Code: CH2303
Subject Name: Chemical Reaction Engineering-I

Shroff S.R. Rotary Institute of Chemical Technology

Semester: V

Type of course: Professional Core Course-VIII

Prerequisite: Basic knowledge of material & energy balance in chemical engineering, laws of thermodynamics.

Rationale: The objective of this subject is to study concepts of reaction rate, different method of analysis of kinetic data for experimental determination of rate equations, design of ideal batch and continuous reactors, comparison of chemical reactor performance, optimization of selectivity in multiple reactions, consideration of temperature and pressure effects, etc.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	4	70	30	30	20	150

Sr. No	Content	Total Hrs.
	SECTION-A	
1.	**Overview of Chemical Reaction Engineering:** Classification of reactions, variables affecting rate, definition of reaction rate, single and multiple reactions, elementary and non-elementary reactions, molecularity and order of reaction.	**4**
2.	**Kinetics of Homogeneous Reactions:** Concentration dependent term of rate equation, kinetic models for non-elementary reactions, testing kinetic models, steady state approximation and rate limiting step theory, temperature dependent term of rate equations from Arrhenius theory and comparison with collision and transition state theory, activation energy and temperature dependency.	**6**
3.	**Interpretation of Kinetic Data:** Constant volume and variable volume batch reactor, analysis of total pressure data obtained from a constant-volume batch reactor, development of integral forms of rate equations for simple and complex reactions, analysis of kinetic data using integral, differential, and half-life method.	**8**
	SECTION-B	
4.	**Design of Reactors for Single Reaction:** Performance equations for ideal batch, plug flow, back-mix flow and semi batch reactors for isothermal condition, Size comparison of single reactors, multiple-reactor systems, recycle reactor, optimum recycle operations.	**7**
5.	**Design of Reactors for Multiple Reaction:** Introduction to multiple reactions, qualitative and quantitative treatment of product distribution, reactor size and the	**3**

	selectivity.	
6.	**Temperature Effects:** Calculations of heat of reaction and equilibrium constants from thermodynamics, equilibrium conversion, and general graphical design procedure, optimum temperature progression, energy balances equations in adiabatic and non-adiabatic case, exothermic reaction in mixed flow, rules for choice of reactors and optimum operation of rectors.	**8**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
20	30	30	10	10	-

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Textbooks:

1. Octave Levenspiel, Chemical Reaction Engineering, Third Edition, John Wiley and Sons, 2006.

Reference Books:

1. J. M Smith, Chemical Engineering Kinetics, 3rd Edition, McGraw-Hill, 1981.
2. H. Scott Fogler, Elements of Chemical Reaction Engineering, 4th Edition, Prentice Hall International, 2016.

List of Practicals:

Sr. No.	Practicals	Approx. Hours required
1.	Study the effect of concentration on rate of chemical reaction.	2
2.	Study the effect of temperature on rate of chemical reaction.	2
3.	Study the homogeneous catalytic reaction.	2
4.	Determine activation energy of chemical reaction.	2
5.	Determination of kinetics of chemical reaction using integral method.	2
6.	Determination of kinetics of chemical reaction using differential method.	2
7.	Determination of kinetics of chemical reaction using half-life time method.	2
8.	Study performance of continuous stirred tank reactor (CSTR).	2
9.	Study performance of plug flow reactor (PFR).	2
10.	Study the adiabatic batch reactor.	2

Bachelor of Engineering
Subject Code: CH2303
Subject Name: Chemical Reaction Engineering-I

Course Outcomes:

After learning this course, students will be able to:

Sr. No.	CO statement
CO-1	Classify the reactions carried out in chemical industry.
CO-2	Demonstrate controlling factors and their effect on rate of reaction.
CO-3	Interpret and analysis kinetics data of a chemical reaction.
CO-4	Derive the performance equation of a reactor and evaluate it.
CO-5	Describe the design of a reactor for complex reaction.
CO-6	Evaluate the performance under various operating temperature conditions.

List of Open Source Software/learning website:

- https://nptel.ac.in/courses/103103153
- http://websites.umich.edu/~elements/

Bachelor of Engineering
Subject Code: CH2304
Subject Name: Process Dynamics and Control

Shroff S.R. Rotary Institute of Chemical Technology

Semester: V

Type of course: Professional Core Course-IX

Prerequisite: Material and energy balance calculations, basics of differential equations**.**

Rationale: The course is designed to introduce the fundamentals of process dynamics and control. The course will teach the students about mathematical models based on transfer function approach for single loop systems, how to obtain dynamic response of open loop and closed loop systems, stability analysis in transient and frequency domains, and controller tuning methods. The course also introduces P, PI, and PID controllers and their applications. The course would end with more advanced concepts like feed-forward control, ratio control, dead-time compensation, and computer based process control.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	4	70	30	30	20	150

Sr. No	Content	Total Hrs.
	SECTION-A	
1.	**Introduction to Process Control:** Need of process control, control systems, steady state and dynamic system, block diagrams, types of variable in process control- process variable, controlled variable, manipulated variable, measured variable. **Laplace Transforms:** Definition, transforms of simple functions, ramp functions, sine functions, inversions of transform function by partial fractions, final value and initial value theorems, transforms of unit impulse functions, transforms of integral.	**7**
2.	**First Order Systems:** Transfer functions for mercury thermometer, liquid level, mixing process, heating process, pure capacitive system definition time constant and steady state gain, transient response of step, sinusoidal and, impulse input functions, first order system in series: interacting and non-interacting system, generalization of several non-interacting systems in series, linearization.	**6**
3.	**Second Order Systems:** Development of transfer functions, damped vibrator, u tube manometer, damping factor , response for step input - overshoot, decay ratio, rise time, response time, period of oscillation, natural period of oscillation, sinusoidal response, phase lag and phase lead, transportation lag, dead time.	**5**

SECTION-B		
4.	**The Control Systems:** Standard block diagram symbols, negative and positive feedback, servo problem v/s regulator problems, development of block diagrams, process measuring element, controller, final control element, closed loop transfer functions, block diagram reduction, overall transfer function for single loop system, overall transfer function for change in load, parts of control system. **Controllers and Final Control Elements:** Proportional control (I), Proportional Integral (PI) control, Proportional Derivative (PD) control, Proportional Integral Derivative (PID) control, transfer functions of P, PI, PD, and PID control, motivation for addition of integral and derivative modes, block diagram of chemical reactor control system, control valve, control valve characteristics, on-off controller.	**7**
5.	**Response of Simple Control Systems:** Proportional control for set point change, proportional control for load change, proportional integral control for load change, proportional integral control for set point change, proportional control for system with measurement lag. **Stability:** Definition of stability, stability criterion, characteristic equation, stability analysis- Routh array, root locus and, Nyquist stability criterion. **Frequency Response Analysis:** First order system, second order system, pure dead time, pure capacitive, non-interacting capacities in series and feedback controllers, Bode diagrams, Bode stability criterion, graphical rules for Bode diagrams, phase margin, magnitude ratio, phase shift, open loop bode diagrams of various controllers.	**7**
6.	**Controller Tuning and Advance Controllers:** Ziegler-Nichols method, Cohen-Coon method, introduction to cascade control, feed forward control, ratio control, dead-time compensation. Introduction to computer process control, PLC, DCS, and SCADA.	**4**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
20	25	25	10	20	0

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Textbooks:

1. D. R. Coughanowr, S. LeBlanc, Process Systems Analysis and Control, 3rd edition, McGraw-Hill, 2008.

Reference Books:

1. G. Stephanopoulos, Chemical Process Control: An Introduction to Theory and Practice, Pearson Education, 1984.
2. D.E. Seborg, T. F. Edgar, D. A. Mellichamp, Process Dynamics and Control, 2nd edition, John Wiley, 2003.

List of Practicals:

Sr. No.	Practicals	Approx. Hours required
1.	To obtain the response of first order thermometer system for step change.	2
2.	To obtain the response of first order liquid level system for step change.	2
3.	To obtain response of Interacting tanks for step change.	2
4.	To obtain response of Non-interacting tanks.	2
5.	To study on temperature, level, flow, and pressure control trainers.	2
6.	To study flow-level cascade control.	2
7.	To study characteristics of flow control valves	2
8.	To study the response of first order system for sinusoidal input change using MATLAB.	2
9.	To study the effect of damping factor on a second order system for step change using MATLAB.	2
10.	To generate a Bode diagram for a given system using MATLAB.	2

Course Outcomes:
After learning this course, students will be able to:

Sr. No.	CO statement
CO-1	Identify different forcing functions of the control process.
CO-2	Obtain the response of physical systems for different forcing functions.
CO-3	Analyze the response of the feedback control system for set point and load change.
CO-4	Understand the effects of P, PI, PD, and PID controllers on a controlled process.
CO-5	Perform stability analysis and frequency response analysis for a given dynamic system.
CO-6	Evaluate the parameters required for controller tuning.

List of Open Source Software/learning website:

- https://nptel.ac.in/courses/103/106/103106148/

Bachelor of Engineering
Subject Code: CH2305
Subject Name: Material Science and Engineering

Shroff S.R. Rotary Institute of Chemical Technology

Semester: V

Type of course: Professional Elective -II

Prerequisite: Basic of Chemistry and Physics.

Rationale: This course has been intended to introduce the engineering to the properties related to the structure and the characteristics of various types of materials used in the chemical industries. New materials are being developed & it is possible change the properties of materials to suit the requirements. This course aims at developing knowledge on various types of materials.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
03	0	0	03	70	30	00	00	100

Sr. No	Content	Total Hrs.
	SECTION-A	
1.	**Introduction to Materials:** Bonding between atoms: metallic, ionic, covalent, Van der Waals forces, role of materials selection in design, structure property-processing-performance relationships,	**6**
2.	**Metal and their Alloys: (Ferrous Materials):** Pure iron, cast iron, mild steel, stainless steels, special alloy steels, iron and iron carbide, phase diagram: heat treatment of carbon steels. **Metal and their Alloys: (Non-ferrous Materials):** Lead, tin, aluminum, zinc, nickel, copper, magnesium and their alloys, properties and applications in process industries.	**6**
3.	**Hydrocarbon Materials (Polymers):** Natural and synthetic polymeric materials, polymer material structure and properties, deformation, flow and melt characteristics, morphology and order in crystalline polymers, mechanical properties of polymers, polymer structure and physical properties correlation.	**6**
	SECTION-B	
4.	**Ceramic, Glasses and Cement:** definition of ceramics and glasses, interaction between structure, processing, and properties, applications of ceramic and glass materials, crystalline and non-crystalline ceramics	**6**
5.	**Corrosion:** Types of corrosions, dry and wet corrosion, study of electro chemical and oxidation corrosion, Corrosion prevention anodic and cathodic prevention and	**6**

	coatings.	
6.	**Composite material:** Introduction to composite materials: definition, classification & brief history of composite materials, constituent of composite materials: reinforcements, matrix, coupling agents, coatings & fillers.	**6**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
30	35	35	00	00	00

Legends: R: Remembrance, U: Understanding, A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Textbooks:

1. V. D. Kodgire, Material Science and Metallurgy for Engineers, 44th edition, Everest Publication India, 2018.

Reference Books:

1. K. G. Budinsky, K. M. Budinsky, Engineering Materials- Properties and Selection, 9th edition, Prentice Hall of India, 2009.
2. H. R. Clauster, Industrial and Engineering Materials, McGraw Hill Book Co. India, 1995.
3. J. L Lee. and Evans, Selecting Engineering Materials for Chemical and Process Plants, Business Works, New York, 1974.
4. V. Raghavan, Material Science and Engineering, 4th edition, PHI Learning Private Limited, India, 2015.
5. V. R. Gowarikar, N. V. Vishwanath, J. Shreedhar. Polymer Science, New Age International Publication, India, 1986.

Course Outcomes:

After learning this course, students will be able to:

Sr. No.	**CO statement**
CO-1	Understand the significance of different material.
CO-2	Compare properties of metals and alloys to select appropriate metal for desired application.
CO-3	Analyze properties of hydrocarbon materials and recommend proper material for desired application.
CO-4	Select appropriate ceramic and glass material for intended application.

CO-5	Propose different types of corrosion protective material for different conditions at workplace. .
CO-6	Apprehend and effective use of properties in design of composite structures.

List of Open Source Software/learning website:

- https://nptel.ac.in/courses/113102080

Bachelor of Engineering
Subject Code: CH2306
Subject Name: Polymer Science and Technology

Shroff S.R. Rotary Institute of Chemical Technology

Semester: V

Type of course: Professional Elective -II

Prerequisite: Basic knowledge of material and its properties.

Rationale: The main theme of this course is to focus on understanding of polymer science, its technology, polymer synthesis and its characterization. Knowledge of properties of polymers will enable their proper selection for applications in domestic as well as industrial appliances.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	0	3	70	30	00	00	100

Sr. No	Content	Total Hrs.
	SECTION-A	
1.	**Introduction:** Basic concept of monomer, polymer, structure of polymers, classification of polymers, concept of average molecular weight, number and weight average molecular weight, poly-dispersity, degree of polymerization, significance of polymer molecular weight, size of polymer molecules.	**4**
2.	**Molecular Weight and its Distribution**: Determination (Mn to Mz & MWD), Carother's equation, states of polymers, transition temperatures such as Tg, Tc, Tm, solubility parameter, solution properties, temperature, good/ bad solvent.	**4**
3.	**Polymerization:** Introduction, functionality, different initiating systems such as free radicle polymerization, redox, cationic & anionic polymerization, condensation polymerization, comparison of these systems with advantages & disadvantages, **Methods of Polymerization:** Bulk, solution, suspension, emulsion, interfacial polymerization.	**10**
	SECTION-B	
4.	**Classification, Role, Mechanism, Suitability and Examples of following Additives:** Additives which assist in processing: stabilizers, lubricants, processing aids, additives which modify mechanical properties, plasticizers, reinforcing fillers, nano fillers, toughening agents, additives which reduce formulation costs, fillers and extenders, anti-ageing additives: UV stabilizers, antioxidants.	**6**
5.	**Polymer Degradation:** Polymer degradation (chain and random), methods of	**6**

	degradation of polymers such as mechanical, thermal, photo, oxidative and bio degradation.	
6.	**Processing of polymers:** Unit operations in polymer industries, polymer processing, moulding, calendaring, extrusion etc.	**6**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
20	25	25	10	20	00

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Textbooks:

1. V. R. Gowarikar and N. V. Viswanathan, Polymer Science, Willey, 1986.

Reference Books:

1. Premamoy Ghosh, Polymer Science and Technology, Tata McGraw Hill, 2011.
2. N.G McCrum, Principles of Polymer Engineering, 2nd edition, Oxford University press, 1997.
3. George Odian Principles of Polymerization, Wiley Interscience, 2004.
4. G.S. Misra, Introductory Polymer Chemistry, Willey eastern limited, 1993.

Course Outcomes:

After learning this course, students will be able to:

Sr. No.	**CO statement**
CO-1	Describe the basic concepts of monomer, polymer, degree of polymerization, and repeating units and their properties.
CO-2	Understand the concept of molecular weight.
CO-3	Discuss general techniques of polymerizations, uses and applications.
CO-4	Explain the properties, types and mechanism of processing aids, mechanical property modifiers and anti-ageing additives.
CO-5	Differentiate degradation methods of polymer.
CO-6	Compare the different molding techniques.

List of Open Source Software/learning website:

- https://nptel.ac.in/courses/104105039

Bachelor of Engineering
Subject Code: CH2308
Subject Name: Fuel Cell Technology

Shroff S.R. Rotary Institute of Chemical Technology

Semester: V

Type of course: Open Elective -II

Prerequisite: Fundamental of Mechanical, Fluid Flow, Mass and Heat Transfer Operations.

Rationale: The objective of this course is to provide basic knowledge of fuel cells. Which includes the classification, working and chemistry of fuel cell. Selection and processing of fuels for fuels cells. Design process of fuel cell etc.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	0	3	70	30	00	00	100

Sr. No	Content	Total Hrs.
	SECTION-A	
1.	**Overview of Fuel Cells:** Brief history, classification, working principle, need of fuel cells, fuel cell basic chemistry and thermodynamics, heat of reaction, theoretical electrical work and potential, theoretical fuel cell efficiency.	**6**
2.	**Fuels for Fuel Cells:** Hydrogen, hydrocarbon fuels, effect of impurities such as CO, Sulphur and others.	**6**
3.	**Fuel Cell Electrochemistry:** Electrode kinetics, types of voltage losses, polarization curve, fuel cell efficiency, Tafel equation, exchange currents.	**6**
	SECTION-B	
4.	**Fuel Cell Process Design:** Main PEM fuel cell components, materials, properties and processes: membrane, electrode, gas diffusion layer, bi-polar plates, fuel cell operating conditions: pressure, temperature, flow rates, humidity.	**6**
5.	**Components of Fuel Cell:** Components of solid-oxide fuel cells, cell stack and designs, electrode polarization, testing of electrodes, cells and short stacks, cell, stack and system modeling	**6**
6.	**Fuel Processing:** Direct and in-direct internal reforming, reformation of hydrocarbons by steam, CO_2 and partial oxidation, direct electro-catalytic oxidation of hydrocarbons, carbon decomposition, sulphur tolerance and removal, using renewable fuels for SOFCs	**6**

Suggested Specification table with Marks (Theory):

Bachelor of Engineering
Subject Code: CH2308
Subject Name: Fuel Cell Technology

Shroff S.R. Rotary Institute of Chemical Technology

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
30	35	25	10	00	00

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Textbooks:

1. Subhash C. Singal and Kevin Kendall, High Temperature Fuel Cells: Fundamentals, Design and Applications, 2003.
2. R. P. O'Hayre, S. Cha, W. Colella, F. B. Prinz, Fuel Cell Fundamentals, Wiley, NY 2006.

Reference Books:

1. G. Hoogers, Fuel Cell Technology Hand Book, CRC Press, 2003.
2. Karl Kordesch& Gunter Simader, Fuel Cells and Their Applications, VCH Publishers, NY, 2001.
3. F. Barbir, PEM Fuel Cells: Theory and Practice, 2nd Ed., Elsevier/Academic Press, 2013.

Course Outcomes:

After learning this course, students will be able to:

Sr. No.	CO statement
CO-1	Understand the basics of fuel cells.
CO-2	Select the fuels for different types of fuel cell.
CO-3	Determine the kinetics and efficiency of fuel cells.
CO-4	Explain design of fuel cells.
CO-5	Elaborate the components of fuel cells.
CO-6	Discuss processing of fuels for fuel cells.

List of Open Source Software/learning website:

- https://nptel.ac.in/courses/103105161

Bachelor of Engineering
Subject Code: CH2309
Subject Name: Fuels and Combustion

Shroff S.R. Rotary Institute of Chemical Technology

Semester: VI

Type of course: Open Elective-II

Prerequisite: Engineering Thermodynamics

Rationale: Fuel plays an important role in an industry for power generation and for providing process heat. Students will learn about classification of industrial fuel techniques and combustion technology.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	0	3	70	30	00	00	100

Content:

Sr. No	Content	Total Hrs.
	SECTION-A	
1.	**Classification and Properties of Fuels:** Fuels-types and characteristics of fuels-determination of properties of fuels-fuel analysis- proximate and ultimate analysis-calorific value (CV)-gross and net calorific values (GCV,NCV), bomb calorimeter.	**5**
2.	**Solid Fuels:** Origin of coal –analysis of coal, gasification and liquefaction properties of coal, oxidation of coal, efficient use of solid fuels, solid fuel handling.	**7**
3.	**Liquid Fuels:** Origin and classification of petroleum, refining and other conversion processes, composition of petroleum with respect to combustion, property and testing of petroleum products and advanced biofuels, biodiesel.	**6**
	SECTION-B	
4.	**Gaseous Fuels:** Natural gas, LPG, CNG, methane, producer gas, water gas, hydrogen, Sustainable aviation fuel (SAF), gasification efficiency	**5**
5.	**Combustion:** General principles of combustion-types of combustion processes, combustion chemistry and combustion calculations-air fuel ratio.	**6**
6.	**Combustion Equipments:** Analysis of flue gases by Orsat apparatus-combustion of solid fuels-grate firing and pulverized fuel firing system-fluidized bed combustion, burners.	**7**

Suggested Specification table with Marks (Theory):

Bachelor of Engineering
Subject Code: CH2309
Subject Name: Fuels and Combustion

Shroff S.R. Rotary Institute of Chemical Technology

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
30	35	20	15	-	-

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Textbooks:

1. S. Sarkar, Fuels and combustion, 3rd edition, Universities Press, India, 2009.

Reference Books:

1. J. G. Speight, The Chemistry and Technology of Coal, 3rd edition, Taylor and Francis Ltd., USA, 2016.
2. K. Kenneth, Principles of combustion, 2nd edition, Wiley and Sons, 2005.
3. S.P. Sharma and C. Mohan, Fuels and combustion, Tata McGraw-Hill, 1984.

Course Outcomes:

After learning this course, students will be able to:

Sr. No.	CO statement
CO-1	Classify the various types of fuels like liquid, solid and gaseous fuels.
CO-2	Describe the properties and applications of solid fuels (coal).
CO-3	Discuss the properties and composition of petroleum.
CO-4	Explain the types of gaseous fuels.
CO-5	Apply the principles of combustion to various fuels.
CO-6	Compare the different equipments used in combustion.

List of Open Source Software/learning website:

- https://archive.nptel.ac.in/courses/103/105/103105110

Shroff S.R. Rotary Institute of Chemical Technology

Type of course: Work-Personality Development

Prerequisite: To keep open mind and will to learn humanity for oneself and society.

Rationale: The Contributor Program aims to accomplish the following outcomes in the lives of students–

- Improve the employability of students by giving them the right work ethic and thinking that employers are looking for.
- Build their confidence with which they can go into any job and contribute meaningfully.
- Improve their ability to engage better in the workplace and to be able to handle the challenges that come up there.
- Build their career-worthiness and help them develop into future-ready contributors with ability to navigate a career in a volatile, changing world.
- Widen their choices of career and success, so that they are able to open up more opportunities for themselves and take up unconventional career pathways.
- Enable them to recognize how they, as technical professionals, can participate and make a positive contribution to their communities and to their state.

Towards this goal, the Contributor Program has been designed to awaken and strengthen students from within, in terms of building positive self-esteem, increasing their confidence level and I-can attitude, improving their aspirations, giving them new methods of thinking, building their cognitive capacities, exposing them to the skills and practices associated with being contributors in the workplace (not mere employees).

The Program content is also designed to expose students to real-world workplace scenarios and sensitize them to some of the challenges faced in society around them, especially in the local communities around them and in their own state of Gujarat.

The Contributor Program syllabus has been evolved and fine-tuned over several years, (a) to address the changing need and contemporary challenges being faced by industry and what employers of today are looking for in the people they hire and (b) by working extensively with universities and students building an appreciation of their challenges and concerns. At the core, the program is guided by the higher ideas and principles of practical Vedanta in work.

Bachelor of Engineering
Subject Code: MH2301
Subject Name: Contributor Personality Development Program – 1

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
1	1	0	2	50	30	00	20	100

Note:

- Weekly 2 hours of Classroom facilitated sessions are planned which include Solutioning and Self- discovery sessions.
- In addition, there will be individual/ team projects as part of Practical's. Students can do this on their own, with faculty as guide.

Note:

It is the responsibility of the institute heads that marks for PA of theory & ESE and PA of practical for each Students are entered online into the UPL University Portal at the end of each semester within the dates Specified by UPL University.

Content:

Sr. No.	Content	Total Hrs.
	SECTION-A	
1	**The Contributor Work Ideal** In this topic, students explore what is their "ideal" of work - is the ideal to be a "worker" or to be a "contributor"? For example, an employee who has the ideal of a "worker" goes to work to pass time, earn a living, get benefits; in contrast to an employee with the ideal of a "contributor" who wants to make a difference, get things done well, create value for the company. This enables students to transform their expectation of themselves in work	04 hrs Classroom engagement (including self-discovery/ solutioning sessions)

2	**Identity & Self-esteem** In this topic, students engage with the question "who am I?" or on what basis they define themselves. Is their identity defined by what others think of them (extrinsic self-esteem) or by what they think of themselves (intrinsic self-esteem)? Further, they discover positive identities that lead to intrinsic self-esteem, such as an I-can identity based on one's capacity and inner strength. This enables them to build confidence and self-esteem.	04 hrs Classroom engagement (including self-discovery/ solutioning sessions)
3	**Become a Creator of one's destiny** In a "victim stance", we see the career environment as full of difficulties and hurdles. We feel powerless or blame our circumstances for not having many opportunities. This makes us fearful of uncertainty and makes us settle for jobs where we remain mediocre. In this topic, students discover the "creator of destiny stance" to challenges and situations. This stance frees them to try out new things, open up new possibilities, take on responsibility, and see the opportunity hidden in their environment.	04 hrs Classroom engagement (including self- discovery/ solutioning sessions)
	SECTION-B	
4	**Achieving Sustainable Success** In this topic, students discover how to achieve sustainable or lasting success, by building one's "engine of success", making them success- worthy. Where their focus shifts to building one's "engine of success"rather than being on chasing the "fruits of success". This is important, because over a lifetime of work, all people go through ups and downs – where the fruits are not in their control. People who are focused on the fruits of success, fall prey to disappointment, loss in motivation, quitting too early, trying to find shortcuts – when fruits don't come. Whereas people focused on building their engine of success continue to contribute steadily, irrespective of whether fruits come or not. And with a strong engine of success, fruits come to them in time.	04 hrs Classroom engagement (including self- discovery/ solutioning sessions)

5	**Career Development Models** In this topic, students explore a range of diverse "career development models" and the possibilities for contribution each opens up to them (e.g. start-up career model, change-maker career model, etc.). This opens their mind to different and even unconventional career models possible, beyond the usual (such as "stable large company career model" where one gets an engineering degree, then MBA, then get a job in a large company). This frees them from a herd mentality when making career choices.	04 hrs Classroom engagement (including self- discovery/ solutioning sessions)
6	**Expanding contribution in every role** In this topic, students explore the many roles they can play in their life & discover the power they have to expand the contribution possible in any role. (E.g. role of student, role of manager, role of a project site engineer). So, the potential of a role is in the individual's hands. This opens their mind to an alternative way of career growth.	04 hrs Classroom engagement (including self- discovery/ solutioning sessions)

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
-	**20**	**20**	**20**	**20**	**20**

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Reference resources:

A. Basic reference for both students and teachers

1. Contributor Personality Program textbook cum workbook developed by Illumine

2. Web-based ActivGuide™ for self-exploration of rich media resources to vividly understand many of the ideas, watch role models, learn from industry people, get reference readings – that help them enrich the understanding they gained in the class published by Illumine Foundation

B. Advanced reference for teachers

1. On Contributors, Srinivas V.; Illumine Ideas, 2011
2. Enlightened Citizenship and Democracy; Swami Ranganathananda, Bharatiya Vidya Bhavan, 1989
3. Eternal Values for a Changing Society – Vol I-IV, Swami Ranganathananda; Bharatiya Vidya Bhavan
4. Karma Yoga, Swami Vivekananda; Advaita Ashrama
5. Vivekananda: His Call to the Nation, Swami Vivekananda; Advaita Ashrama
6. Six Pillars of Self Esteem, Nathaniel Branden; Bantam, 1995
7. Mindset: The New Psychology of Success, Carol S. Dweck; Random House Publishing Group, 2007
8. Lasting Contribution: How to Think, Plan, and Act to Accomplish Meaningful Work, Tad Waddington; Agate Publishing, 2007
9. Why not?: how to use everyday ingenuity to solve problems big and small, Barry Nalebuff, Ian Ayres; Harvard Business School Press, 2003
10. The value mindset: returning to the first principles of capitalist enterprise (Ch 8 & 9); Erik Stern, Mike Hutchinson; John Wiley and Sons, 2004
11. The Power of Full Engagement: Managing Energy, Not Time, is the Key to High Performance and Personal Renewal, Jim Loehr, Tony Schwartz; Simon and Schuster, 2003
12. Creating Shared Value, Michael E. Porter and Mark R. Kramer; Harvard Business Review; Jan/Feb2011, Vol. 89 Issue 1/2
13. The Speed of Trust: The One Thing That Changes Everything, Stephen M. R. Covey, Rebecca,R. Merrill, Stephen R. Covey; Free Press, 2008
14. The Courage to Meet the Demands of Reality, Henry Cloud; HarperCollins, 2009
15. Responsibility at work: how leading professionals act (or don't act) responsibly, Howard Gardner; John Wiley & Sons, 200

Bachelor of Engineering
Subject Code: MH2301
Subject Name: Contributor Personality Development Program – 1

Course Outcomes:

Students will be able to:

Sr. No.	CO statement
CO-1	Students will be able to recognize & appreciate two alternative ideals of work – "worker" and "contributor".
CO-2	Students will be able to recognize & appreciate alternative ways in which they could define themselves & their identity – that will lead to building intrinsic self-esteem and confidence in oneself.
CO-3	Students will be able to recognize & appreciate the way people approach challenges and situations; and how it frees individuals to take on challenges and open up Opportunities.
CO-4	Students will be able to differentiate between two alternative approaches to success - 'building one's engine of success' and 'chasing the fruits of success'Lead to sustainable or lasting success in the long run.
CO-5	Students will be able to recognize & appreciate different career models and their Value; to help them make more informed career-related choices.
CO-6	Students will be able to recognize & appreciate how one can expand the contribution possible in any role, thereby opening up an alternative way of career Growth to them.

Prepared By: Ms. Aakancha Sanjeev Kumar

Moderated By: Dr Purvi Naik

Bachelor of Engineering
Subject Code: CH2310
Subject Name: Mass Transfer Operations-II

Shroff S.R. Rotary Institute of Chemical Technology

Semester: VI

Type of course: Professional Core Course-X

Prerequisite: Basics of Fluid Dynamics and Heat Transfer, Mass Transfer-I

Rationale: The objective of this course is to apply the principles of mass transfer operations to specific applications, separation and/or purification processes. The goal is to provide students with the theoretical/analytical aspects to design mass transfer equipment and to deal with complex problems of separations.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	4	70	30	30	20	150

Content:

Sr. No	Content	Total Hrs.
	SECTION-A	
1.	**Introduction of Distillation:**, vapour-liquid equilibria, *P-x-y T-x-y* diagrams, concept of relative volatility and effect of P and T on equilibrium data, ideal solutions, Raoult's Law as applied to distillation operations, deviation from ideality, minimum and maximum boiling azeotropic mixtures, enthalpy- concentration diagrams, flash distillation, steam distillation, simple distillation, continuous rectification, binary systems, batch fractionation etc.	**7**
2.	**Process Design of Distillation:** Determination of number of stages by Ponchon and Severit method and McCabe-Thiele method, concept of minimum, total and optimum reflux ratio, reboilers, use of open steam, partial condensers, cold hot circulating reflux etc. azeotropic distillation, extractive distillation.	**5**
3.	**Humidification Operations:** VLE and enthalpy for pure substances, saturated and unsaturated vapour-gas mixtures and related terminologies such as dry bulb temperature, dew point, wet bulb temperature, percentage & relative saturation, adiabatic saturation temperature, humid heat, humid volume etc. psychometric chart & psychometric relation for air-water system, adiabatic saturation curves, wet bulb temperature theory, Lewis relation, adiabatic operation, cooling towers: its type and calculation of range and approach.	**6**

SECTION-B		
4.	**Adsorption:** Adsorption, definition and industrial application, types of adsorption, nature of commonly used adsorbents, adsorption equilibria, single gases and vapour, adsorption hysteresis, effect of temperature on adsorption, heat of adsorption, adsorption of solute from dilute liquid solution.	**7**
5.	**Ion exchange:** Adsorption from concentrated solutions, material balance and Freundlich equation for single stage operation and multistage cross-current operation, counter current operation, ion-exchange principles, applications, equilibria and rate of ion exchange	**5**
6.	**Drying:** Equilibrium relationship & hysteresis, various types of moisture in drying, batch drying, rate of drying, time of drying, cross-circulation drying, concept of *NoG* and *HoG*, drying at low temperature, freeze drying etc. batch & continuous drying equipments-tray dryer, tunnel dryer, rotary dryers, spray dryers, fluidized bed dryer, etc.	**6**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
25	20	25	20	10	-

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Textbooks:

1. R. E. Treybal, Mass transfer operations, 3rd edition, Mc-Graw Hill international, New Delhi, 1983.

Reference Books:

1. B. K. Dutta, Principles of Mass Transfer and Separation Processes, 2nd edition, Prentice Hall of India, 2007.
2. J. F. Richardson, J. H. Harkar, Coulson and Richardson's Chemical Engineering, Volume-2, 5th edition, Butterworth Heinemann, 2002.
3. W. L. McCabe, J.C .Smith & Harriott, Unit Operations of Chemical Engineering, 6th edition Mc-Graw Hill International, 2001.
4. C. J. Geankoplis, Transport Processes and Unit Operations, 3rd edition, Prentice Hall of India, 1993.

Bachelor of Engineering
Subject Code: CH2310
Subject Name: Mass Transfer Operations-II

Shroff S.R. Rotary Institute of Chemical Technology

List of Practicals:

Sr. No.	Practicals	Approx. Hours required
1.	Evaluation of Simple or Batch distillation	2
2.	Evaluation of Steam distillation	2
3.	Evaluation of Vapor liquid equilibrium	2
4.	Evaluation of Drying in a tray dryer	2
5.	Evaluation of Drying in a fluidized bed dryer	2
6.	Calculate range and approach in cooling tower.	2
7.	Evaluation of adsorption of acetone on charcoal at room temperature.	2
8.	Evaluation of adsorption of acetone on charcoal at elevated temperature.	2
9.	Determination of VLE curve by CHEMCAD.	2
10.	Determination of batch distillation by CHEMCAD.	2

Course Outcomes:

After learning this course, students will be able to:

Sr. No.	CO statement
CO-1	Recall Raoult's law and define it for distillation operations.
CO-2	Demonstrate stage calculations for distillation operations.
CO-3	Develop the concept of humidification and dehumidification.
CO-4	Classify different type of adsorption and its applications.
CO-5	Compare adsorption and ion exchange for different applications.
CO-6	Estimate the performance of different dryers using basic concept of drying.

List of Open Source Software/learning website:

- https://archive.nptel.ac.in/courses/103/103/103103145/

Bachelor of Engineering
Subject Code: CH2311
Subject Name: Chemical Reaction Engineering-II

Shroff S.R. Rotary Institute of Chemical Technology

Semester: VI

Type of course: Professional Core Course-XI

Prerequisite: Knowledge of Chemical Reaction Engineering-I

Rationale: This subject mainly covers heterogeneous reaction and non-ideal reactors, catalysis. The first part of this subject deals with kinetics and design of reactors for non-catalytic fluid-fluid and fluid-particle reactions. While the second part consist of catalysis, catalytic reaction kinetics and the non-ideal reactors.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	4	70	30	30	20	150

Content:

Sr. No	Content	Total Hrs.
	SECTION-A	
1.	**Heterogeneous Reactions: Introduction:** Steps involved in heterogeneous systems, Overall rate expression for linear and nonlinear process, contacting patterns for two-phase systems.	**2**
2.	**Fluid-Fluid systems:** Importance of fluid-fluid reactions, rate equation for straight mass transfer, kinetic regimes of mass transfer and chemical reaction, rate equation for mass transfer and chemical reactions, film conversion parameter, selection criteria for contacting devices, fluid-fluid reactor design.	**8**
3.	**Fluid-Particle systems:** Importance of fluid-particle reactions, fluid particle reaction kinetics, selection of a model, Shrinking Core Model for unchanging and changing size spherical partials, diffusion through gas film and through ash layer controlling, chemical reaction controlling, Shrinking Core Model, its limitations, Determination of rate controlling step.	**8**
	SECTION-B	
4.	**Catalysis:** Catalysts, physical properties of catalyst, surface area, void volume, solid density, pore volume distribution, classification and preparation of catalyst, catalyst promoters, catalyst inhibitors, catalyst poisons, nature and mechanism of catalytic reactions.	**5**

5.	**Solid-Catalyzed reactions: Kinetics:** Adsorption isotherms and rates of adsorption and desorption, kinetic regimes, rate equations for surface kinetics, pore diffusion, determining rate controlling step, experimental methods for finding rates, product distribution in multiple reactions, packed bed catalytic reactors, fluidized bed reactors, trickle beds, slurry reactors, introduction to LHHW (Langmuir-Hinshelwood-Hougen-Watson) kinetic model.	**7**
6.	**Non-Ideal Flow:** Basics of non-ideal flow, Residence time distribution, stimulus response techniques, The E,F and C Curves, their interrelationship, conversion in non-ideal flow reactors, Dispersion model, Chemical Reaction and dispersion, Intensity of fluid mixing. Tanks in series model, Deviation from plug flow, Models for real stirred tanks.	**6**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
20	30	20	15	15	-

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Textbooks:

1. Octave Levenspiel, Chemical Reaction Engineering, 3rd edition, John Wiley and Sons, 2006.

Reference Books:

1. J. M Smith, Chemical Engineering Kinetics, Second Edition, McGraw-Hill, 1970.
2. H. Scott Fogler, Elements of Chemical Reaction Engineering, Fourth Edition, Prentice Hall International, 2008.
3. J. J. Carberry, "Chemical and Catalytic Reaction Engineering", McGraw Hill, New York, 1976.

List of Practicals:

Sr. No.	**Practicals**	**Approx. Hours required**
1.	Study the properties of solid catalyst particle.	2
2.	Study the effect of absorbate concentration on adsorption.	2
3.	Study the effect of amount of adsorbent on adsorption.	2
4.	Study the effect of temperature of adsorption.	2
5.	Study the fluid-fluid reaction kinetics with straight mass transfer.	2

6.	Study the fluid-fluid reaction kinetics with chemical reaction.	2
7.	Study the fluid-particle reaction of unchanging size of particle.	2
8.	Study the fluid-particle reaction of changing size of particle.	2
9.	RTD studies in Continuous Stirred Tank Reactor (CSTR).	2
10.	RTD studies in Plug Flow Reactor (PFR).	2

Course Outcomes:

After learning this course, students will be able to:

Sr. No.	CO statement
CO-1	Demonstrate the steps involved in heterogeneous reactions.
CO-2	Describe the fluid-fluid reactions and selection of contacting devices.
CO-3	Determine rate controlling step in fluid-solid reactions.
CO-4	Classify catalysts and determine physical properties of catalyst.
CO-5	Understand the nature and mechanism of catalytic reactions
CO-6	Illustrate the non-ideal system using different models.

List of Open Source Software/learning website:

- https://nptel.ac.in/courses/103101141

Bachelor of Engineering
Subject Code: CH2312
Subject Name: Petroleum Refining and Petrochemicals

Shroff S.R. Rotary Institute of Chemical Technology

Semester: VI

Type of course: Professional Elective -III

Prerequisite: Basics of Chemical Process Technology.

Rationale: Petroleum refining as well as petrochemical industries constitute a major part of chemical sector. Every chemical engineer has to invariably handle the enormous consumption of petroleum products, their diversity and increasing applications. Chemical engineer has to apply the relevant concepts for operating petroleum refinery or petrochemical plant in a safe manner. Beside this, a chemical engineer must be aware about the various properties of petroleum fractions as well as petrochemicals. Hence, this course has been designed to develop such expertise and skills.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	4	70	30	30	20	150

Content:

Sr. No	Content	Total Hrs.
	SECTION-A	
1.	**Basics of Petroleum:** Origin and formation of petroleum, reserves and deposits, Indian petroleum industry, composition of crude oils, classification of petroleum, evaluation of crude oil, benchmark crudes.	**4**
2.	**Types of Gases and their Composition:** Types of gasoline & it's important properties and tests such as ASTM distillation, RVP, octane number, oxidation stability, sulphur content, various types of naphtha and their important properties and application, important tests and properties of kerosene such as flash & fire point, smoke point, aniline point, ASTM, TBP, EFV distillation curves.	**7**
3.	**Processing of Petroleum:** Distillation- Pretreatment, Electric desalting, atmospheric and vacuum distillation. **Thermal & Catalytic Cracking:** Necessity and types of cracking, thermal cracking, FCC, catalytic reforming.	**7**
	SECTION-B:	
4.	**Manufacturing Processes for Petrochemicals (C1):** Properties, uses, manufacturing processes, flow-sheets and manufacturing problems of methanol,	**4**

	formaldehyde, chloromethane, ethylene, ethylene dichloride.	
5.	**Manufacturing Processes for Petrochemicals (C2):** properties, uses, manufacturing processes, flow-sheets and manufacturing problems of vinyl chloride, ethylene oxide, ethylene glycol, ethanol amines.	**7**
6.	**Manufacturing Processes for polymers:** Properties, uses, manufacturing processes, flow-sheets and manufacturing problems of BTX separation, p-xylene, styrene, LDPE, LLDPE, HDPE, SBR, polyesters.	**7**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
30	35	20	15	-	-

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E:Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Textbook:

1. B. K. Bhaskara Rao, A textbook on Petrochemicals, 2nd edition, Khanna Publishers, Delhi, 1998.

Reference Books:

1. B. K. Bhaskara Rao, Modern Petroleum Refining Processes, 4th edition, Oxford & IBH Co. Pvt. Ltd., 2002.
2. R. Prasad, Petroleum Refining Technology, Khanna Publishers, 2000.
3. J. C. Speight, The Chemistry and Technology of Petroleum, 3rd edition, Marcel Dekker, 1999.
4. A. G. Lucas, Modern Petroleum Technology, Vol. 2, 6th edition, John Wiley & Sons Limited, 2000.
5. R. N. Watkins, Petroleum Refinery Distillation, 2nd edition, Gulf Pub. Co., 1979.
6. G. N. Sarkar, Advance Petroleum Refining, Khanna Publishers, 1998.

List of Practicals:

Sr. No.	**Practicals**	**Approx. Hours required**
1.	To determine the flash and fire point of given sample of oil using Pensky-Marten apparatus.	2
2.	To determine the softening point and penetration index of Bitumen.	2
3.	To determine the cloud and pour point of a given oil sample.	2
4.	To determine the aniline point of a given sample.	2

5.	To characterize the given petroleum product (Diesel, petrol etc.) by A.S.T.M distillation (To plot ASTM curve)	2
6.	To determine the smoke point of given kerosene (with and without acid treatment) sample using smoke point apparatus.	2
7.	To determine the carbon residue of given sample by rams bottom apparatus.	2
8.	To determine the viscosity of given sample using say bolt viscometer at different temperatures.	2
9.	To determine Reid vapour pressure of a given petroleum fraction.	2
10.	To determine the carbon residue of given sample by Conradson apparatus.	2

Course Outcomes:

After learning this course, students will be able to:

Sr. No.	CO statement
CO-1	State the composition of crude oil and its exploration.
CO-2	Describe the various test properties of crude oil and petroleum products and also explain their physical significance.
CO-3	Explain crude oil processing, pre-treatment techniques.
CO-4	Discuss the treatment techniques for crude oil.
CO-5	Compare the relationship between the types of cracking operations.
CO-6	Formulate the pathways for the manufacture of various petrochemicals.

List of Open-Source Software/learning website:

- https://nptel.ac.in/courses/103102022

Bachelor of Engineering
Subject Code: CH2313
Subject Name: Multicomponent Distillation

Shroff S.R. Rotary Institute of Chemical Technology

Semester: VI

Type of course: Professional Elective III

Prerequisite: Mass Transfer operations, Process Equipment Design.

Rationale: The objective of this course is to apply the principles of mass transfer operations to specific applications, separation and/or purification processes which involves multi components. The goal is to provide students with the theoretical/analytical aspects to design multi component distillation equipment and to deal with complex problems of separating multi components.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	1	0	4	70	30	30	20	150

Sr. No	Content	Total Hrs.
	SECTION-A	
1.	**Selection of Key Component And Operating Pressure:** Light and heavy key component, split key and adjacent key, distribution of key and non-key components, determination of operating pressure for the various industrial distillation columns, criteria for vacuum distillation, advantages & disadvantages of vacuum distillation, determination of vapor-liquid equilibrium data, sequencing of distillation column: concept, selection criteria with industrial examples	6
2.	**Methods for Finding Theoretical Stages:** Short cut methods: Fenskey-Underwood-Gilliland's method, Rigorous methods: Lewis-Metheson method, Theile-Geddes method.	7
3.	**Azeotropic and Extractive Distillation:** Concept and working principle, industrial examples, determination of number of theoretical stages for azeotropic and extractive distillation, advantage and disadvantage over each other.	5
	SECTION-B	
4.	**Tower Diameter and Pressure Drop:** Criteria of selection between tray tower and packed tower, various type of packing, selection of tray type, determination of tower diameter and pressure drop, tray efficiency and HETP.	7
5.	**Multicomponent Batch Distillation:** Design of multicomponent batch distillation with and without rectification.	6
6.	**Energy Saving in Distillation:** Optimum design of system, use of high efficiency trays, heat integration, advanced process control, thermally coupled distillation	5

	column, use of heat pumps, efficient operation of distillation column, replace the distillation partially or completely with new separation techniques.	

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
15	30	25	10	20	00

Legends: R: Remembrance, U: Understanding, A: Application, N: Analyze and E:Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Textbooks:

1. S. B. Thakore, B. I. Bhatt, Introduction to Process Engineering and Design, McGraw Hill, 2nd Edition, 2015.

Reference Books:

1. W. L. McCabe, J. C. Smith, P. Harriott, Unit Operations of Chemical Engineering, 7th Ed., McGraw-Hill Book Co, 2005.
2. E. E. Ludwig, Applied process design for chemical and petrochemical plants , volume 1,2 & 3, 3rd edition, Butterworth- Heinemam, 1997
3. Ray Sinnott, Gavin Towler, Chemical Engineering Design - Principles, Practice and Economics of Plant and Process Design, Butterworth - Heinemann, 2008.

List of Tutorials:

Sr. No.	Exercise	Approx. Hours required
1	Importance of multicomponent distillation in industries.	1
2	Explain key components and their material balance in the distillation.	1
3	Selection of distillation sequence for energy efficient design.	1
4	Design the tray tower using FUG method.	1
5	Using CHEMCAD simulate the multicomponent distillation.	1
6	Optimization of operating conditions for maximum purity and yield in multicomponent distillation.	1
7	Using CHEMCAD converge the Extractive distillation.	1
8	Estimate tower diameter and pressure drop in tray tower.	1
9	Design multicomponent batch distillation.	1
10	Analysis of energy efficiency in multicomponent distillation.	1

Bachelor of Engineering
Subject Code: CH2313
Subject Name: Multicomponent Distillation

Shroff S.R. Rotary Institute of Chemical Technology

Course Outcomes:

After learning this course, students will be able to:

Sr. No.	CO statement
CO-1	Select key component and pressure of column
CO-2	Calculate number of theoretical and actual stages required for multi component distillation by using various methods.
CO-3	Understand how to break azeotrope using azeotropic and extractive distillation.
CO-4	Calculate tower diameter and operating pressure for multi distillation column.
CO-5	Design multicomponent batch distillation.
CO-6	Understand various design options for energy conservation in distillation column.

List of Open Source Software/learning website:

https://nptel.ac.in/courses/103103145

Bachelor of Engineering
Subject Code: CH2315
Subject Name: Process Safety Management

Shroff S.R. Rotary Institute of Chemical Technology

Semester: VI

Type of course: Professional Electives –IV

Prerequisite: Basic understanding of chemical engineering processes and equipment, plant layout, process instrumentation control, material of construction, knowledge of piping system & basic engineering mathematics.

Rationale: Study toxicology, industrial hygiene and regulations, hazards identification and risk assessment in chemical industries for safe operation of industrial processes.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	0	3	70	30	00	00	100

Sr. No	Content	Total Hrs.
	SECTION-A	
1.	**Introduction:** Safety programs, engineering ethics, accident and loss statistics, acceptable risk, the nature of the accident process, inherent safety. **Toxicology:** Entering of toxicants into biological organisms, toxicological studies, elimination of toxicants from biological organisms, effects of toxicants on biological organisms, TLVS.	**6**
2.	**Development of Industrial Hygiene and Regulations:** National and international regulations, OSHA: process safety management, EPA: risk management plan, material safety data sheets.	**6**
3.	**Fire and Explosions & Prevention:** Fire triangle, flammability characteristics of liquids and vapors, limiting oxygen concentration. **Prevention:** Inerting, vacuum purging, pressure purging, sweep-through purging, siphon purging, static electricity, controlling static electricity, ventilation and sprinkler systems.	**6**
	SECTION-B	
4.	**Process Hazards Identification:** Process hazards checklists, hazards surveys, hazards and operability studies, safety reviews.	**7**
5.	**Process Risk Assessment:** Probability theory, failure rate, reliability, failure probability, mean time between failure, event tree analysis, fault tree analysis, layer of protection analysis.	**7**

6.	**Case Studies:** Case study on significant disaster in the world.	**4**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
10	25	20	20	15	10

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Textbooks:

1. D. A. Crowl, J. F. Louvar, Chemical Process Safety: Fundamentals with Applications, 4th edition, Pearson Publication, 1990.

Reference Books:

2. L. Slote, Handbook of Occupational Safety and Health, John Willey and Sons, New York, 2019.
3. F. P. Lees, Loss of prevention in Process Industries,Vol.1& 2,Butterworth-Heinemann Ltd., London, 1991.
4. H. Koren, M. Bisesi, Handbook of Environmental Health and Safety, Jaico Publishing House, Delhi, 1999.

Course Outcomes:

After learning this course, students will be able to:

Sr. No.	CO statement
CO-1	Describe engineering ethics and basic safety concept.
CO-2	Explain the industrial hygiene and process safety management systems.
CO-3	Apply appropriate technique for fire control.
CO-4	Identify hazards in chemical and allied industries.
CO-5	Examine risk in chemical and allied industries.
CO-6	Understand material safety data sheet.

List of Open Source Software/learning website:

- https://nptel.ac.in/courses/103107156

Bachelor of Engineering
Subject Code: CH2316
Subject Name: Safety and Hazard Management

Shroff S.R. Rotary Institute of Chemical Technology

Semester: VI

Type of course: Professional Electives –IV

Prerequisite: Basic understanding of chemical engineering processes and equipment, plant layout, process instrumentation control, material of construction, knowledge of piping system & basic engineering mathematics.

Rationale: Study toxicology, industrial hygiene and regulations, hazards identification and risk management for safe operation of industrial processes.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE(E)	PA(M)	ESE(V)	PA(I)	
3	0	0	3	70	30	00	00	100

Content:

Sr. No	Content	Total Hrs.
	SECTION-A	
1.	**Introduction:** Introduction to safety management, safety programs, engineering ethics, accident and loss statistics, acceptable risk, the nature of the accident process, inherent safety. **Toxicology:** entering of toxicants into biological organisms, toxicological studies, elimination of toxicants from biological organisms, effects of toxicants on biological organisms, TLVS,	**6**
2.	**Development of industrial hygiene and regulations:** national and international regulations, OSHA: process safety management, EPA: risk management plan, RBPS: Risk-Based Process Safety Management, material safety data sheets, safety policy, Safety officers' duties and responsibilities	**6**
3.	**Fire and Explosions & their Prevention:** fire triangle, flammability characteristics of liquids and vapors, limiting oxygen concentration and inerting, Unconfined Vapour Cloud Explosion (UVCE), Boiling Liquid Expanding Vapour Explosion (BLEVE).	**6**

SECTION-B		
4.	**Safety in Chemical Industry:** Criteria for sitting and layout of chemical plants, hazardous area classification, chemical reactivity, relief sizing. **Process Hazards Identification:** process hazards checklists, hazards surveys, hazards and operability studies, safety review, safety integrity level.	**7**
5.	**Process Risk Assessment:** review of probability theory**,** event tree, fault tree and layers of protection analysis.	**7**
6.	**Case studies**: case studies on significant disaster in the world.	**4**

Suggested specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
15	25	25	20	10	5

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Textbook:

1. D. A. Crowl, J. F. Louvar, Chemical Process Safety: Fundamentals with Applications, 4th Ed., 1990.

Reference Books:

1. L. Slote, Handbook of Occupational Safety and Health, John Willey and Sons, New York, 2019.
2. F. P. Lees, Loss of prevention in Process Industries,Vol.1 and 2, Butterworth-Heinemann Ltd., London, 1991.
3. H. Koren, M. Bisesi, Handbook of Environmental Health and Safety, Jaico Publishing House, Delhi, 1999.

Course Outcomes:

After learning this course, students will be able to:

CO	CO statement
CO-1	Describe toxicology and safety concept.
CO-2	Explain process safety management systems.
CO-3	Apply appropriate technique for fire control.
CO-4	Identify hazards in chemical industries and perform HAZOP study.

CO-5	Examine risk in chemical industries and perform risk assessment.
CO-6	Understand material safety data sheet.

List of Open Source Software/learning website:

- https://nptel.ac.in/courses/103107156

Bachelor of Engineering
Subject Code: CH2317
Subject Name: Waste to Energy

Shroff S.R. Rotary Institute of Chemical Technology

Semester: VI

Type of course: Open Elective-III

Prerequisite: Fundamentals of science and engineering.

Rationale: The course deals with the production of energy from different types of wastes through thermo-chemical and biochemical conversion processes. The major objective of this course is to provide basic knowledge with recent advancements in the technology for the utilization of various types of wastes to produce energy

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	4	70	30	30	20	150

Content:

Sr. No	Content	Total Hrs.
	SECTION-A	
1.	**Introduction to Energy from Waste:** Classification of waste as fuel, agro-based, forest residues, industrial waste, municipal solid waste (MSW), kitchen waste, plastic waste, E-waste, Alternate fuel resource (AFR) - energy production from algae, trans-esterification. **Characterization:** Proximate, ultimate, biochemical analysis, heating values, thermal analysis -TGA/DSC, waste to energy options, thermochemical and biochemical conversion.	**7**
2.	**Biomass Combustion:** Biomass stoves types and designs, fixed bed combustors, fluidized bed combustors, pre-processing and treatment of MSW, refuse derived fuel.	**5**
3.	**Liquefaction, Torrefaction and Pyrolysis:** Hydrothermal liquefaction of biomass, torrefaction process, physical properties of torrefied, biomass pyrolysis of biomass and plastics, slow, fast and flash pyrolysis, affecting parameters, manufacture of charcoal, characterization and applications of the pyrolysis & liquefaction products.	**6**
	SECTION-B	
4.	**Gasification of Biomass and RDF:** Gasification reactions, types of gasifiers-downdraft, updraft and cross draft, fixed bed and fluidized bed gasifiers, characterization and applications of gasification products.	**6**

5.	**Bio-Chemical Conversion:** Anaerobic digestion of biomass for production of biogas, effects of operating parameters, types of biogas plants, cleaning and up gradation of biogas, bio-CNG, fermentation of biomass to produce ethanol, characterization, applications of products.	**6**
6.	**Environmental Impacts of Waste to Energy Conversion Plants:** Life cycle assessment and its application to sustainable waste management, biomass energy programme in India, case studies on sustainable biomass conversion.	**6**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
15	25	25	20	10	5

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Textbooks:

1. N. Klinghoffer & M. Castaldi, Waste to Energy Conversion Technology, 1st edition, Woodhead Publishing, 2013.

Reference Books:

1. G. C. Young, Municipal Solid Waste to Energy Conversion Processes- Economic, Technical and Renewable Comparisons, 1st edition, Wiley, 2010.

List of Practicals:

Sr. No.	**Practicals**	**Approx. Hours required**
1.	To perform preliminary analysis of biomass feedstock.	2
2.	To perform pyrolysis of waste plastic in batch reactor.	2
3.	To perform pyrolysis of E waste in fixed bed reactor.	2
4.	To perform pyrolysis of biomass in batch reactor.	2
5.	To perform pyrolysis of HDPE/LDPE in continuous auger reactor	2
6.	To perform co-pyrolysis of waste plastic and biomass in batch reactor	2
7.	To estimate the kinetic parameters for given thermo gravimetric analysis	2
8.	To produce H_2 from waste industrial effluents.	2
9.	To predict the heating values using mathematic models.	2

10.	To segregate E-waste components using dismantling process.	2

Course Outcomes:

After learning this course, students will be able to:

Sr. No.	CO statement
CO-1	Perform preliminary analysis of feed stocks for thermochemical conversion.
CO-2	Describe various thermo-chemical conversion processes.
CO-3	Understand the potential of various waste for energy and fuel production.
CO-4	Estimate the yields of plastic, biomass and E-waste for different conversion processes.
CO-5	Evaluate the thermochemical conversion of biomass, plastic and E-waste.
CO-6	Conduct life cycle assessment of different feed stocks.

List of Open Source Software/learning website:

- https://onlinecourses.nptel.ac.in/noc21_ch09/preview
- https://www.sciencedirect.com/science/article/pii/B9780128129920000042

Semester: VI

Type of course: Open Elective-III

Prerequisite: Student should know the basics of heat transfer, mass transfer, and fluid flow operations.

Rationale: This course deals with the important utilities required for maintaining the required conditions in chemical plant. This course includes the study of various resources and their utilization, generation of required utilities for chemical plants.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	4	70	30	30	20	150

Content:

Sr. No	Content	Total Hrs.
	SECTION-A	
1.	**Introduction:** Various process utilities, their role and importance in chemical plants. Water, compressed air, steam, heat transfer fluids, vacuum, refrigeration.	**6**
2.	**Water Utilization:** Sources of water and their characteristics, treatment storage and distribution of water, water for use in boilers, cooling purposes, drinking and process, reuse and conservation of water, water resource management.	**6**
3.	**Steam Generation:** Steam generation and its application in chemical process plants, distribution and utilization, Design of efficient steam heating systems, Types of boilers and their operation, Selection and sizing of boilers, waste heat boilers, Steam generation by utilizing process waste heat using thermic fluids.	**7**
	SECTION-B	
4.	**Steam Utilization:** Steam economy, steam condensers and condensate utilization expansion joints, flash tank design, steam traps their characteristics, selection and application, waste heat utilization, lagging, selection and thickness.	**7**
5.	**Heating and Cooling**: Process heating systems using hot oil, glycol and water, waste heat utilization, process cooling systems, non-steam heating system, thermic fluid heater, down-therm heater, temperature range, principle, construction & working.	**5**
6.	**Refrigeration and Chilling**: Refrigeration and chilling systems, nitrogen systems, utilities energy consideration and utilities management issues.	**5**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
30	30	25	15	-	-

Legends: R: Remembrance, U: Understanding, A: Application, N: Analyze and E:Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Textbook:

1. J. Broughton, Process Utility Systems: Introduction to Design, Operation, and Maintenance, The Institution of Chemical Engineers, UK, 1994.

2. D. B. Dhone, Plant utilities, 2nd Edition, Nirali Prakashan, 2012.

Reference Books:

1. Metcalf and Eddy, Wastewater Engineering: Treatment & Reuse, 4th Edition, McGraw Hill Publication, 2004.
2. V. Ganapathy, Steam Generators and Waste Heat Boilers for Process and Plant Engineers, CRC Press, Taylor & Francis Group, 2014.
3. B. A. Mujawar, Process Utilities, 3rd Edition, Nirali Prakashan Publication, 2007.
4. P. L. Ballaney, Thermal Engineering (Engineering Thermodynamics and Energy Conversion Techniues), 1st Edition, 1996.

List of Practicals:

Sr. No.	Practicals	Approx. Hours required
1.	Study of compressors.	2
2.	Study of cooling tower operations.	2
3.	Study of refrigeration system.	2
4.	Study of heating system.	2
5.	Study of vacuum pump.	2
6.	To determine pH of the water and to identify the water quality by pH.	2
7.	To find out the total hardness of the water.	2
8.	To determine Chemical Oxygen Demand (COD) of water.	2
9.	To estimate the salinity (amount of chlorides) of water.	2
10.	To determine the Biochemical Oxygen Demand (BOD) of water.	2

Course Outcomes:

After Learning this course, students will be able to:

Sr. No.	CO statement

CO-1	Understand the importance of process utilities in a chemical plant.
CO-2	Relate various methods for water softening and purification.
CO-3	Illustrate properties and generation of steam.
CO-4	Explain effective steam utilization in a process plant.
CO-5	Discuss various heating and cooling systems utilized in chemical industries.
CO-6	Categorize types and method of refrigeration and chilling.

List of Open Source Software/learning website:

- https://archive.nptel.ac.in/courses/103/107/103107211/

Bachelor of Engineering
Subject Code: CH2319
Subject Name: Nanoscience and Technology

Shroff S.R. Rotary Institute of Chemical Technology

Semester: VI

Type of course: Open Elective-IV

Prerequisite: Fundamental of chemistry and material science

Rationale: To provide understanding towards the synthesis, characterization and applications of nanomaterials. Students will learn the concept of nanotechnology, different techniques for synthesizing nanomaterials, characterization of nanomaterials and its applications in different fields.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	0	3	70	30	00	00	100

Content:

Sr. No	Content	Total Hrs.
	SECTION-A	
1.	**Introduction to nanotechnology:** Introduction, definition, history, classification of nanomaterials, nanoscience and nanotechnology in different fields, preparation, safety and storage issues.	**5**
2.	**Properties of nanomaterials:** Effects of the nanometer length scale, size and shape based properties, physical properties (colour, melting point, density), electrical, optical, mechanical and magnetic.	**5**
3.	**Nanoparticles synthesis** Top down and bottom-up approach, colloids, emulsions, micelles, polymers, mechanical attrition and high energy ball milling, chemical reduction methods, precipitation methods. **Fabrication:** Lithography, chemical vapor deposition, physical vapor deposition, sol-gel synthesis, molecular self-assembly, crystal growth, epitaxy, etching, masking.	**8**
	SECTION-B	
4.	**Types of nanomaterials:** Nanoclusters, solid solutions, thin film, nanocomposites (metal oxide and polymer based), core shell nanostructure, bucky balls, carbon nano tubes and, zeolites minerals, dendrimers, micelles, liposomes, block copolymers, porous materials, metal nanocrystals, semiconductor nanomaterials.	**5**
5.	**Nanomaterials characterization:** Scanning electron microscopy, Transmission electron microscopy, Fourier transform infrared spectroscopy, Energy dispersive spectroscopy, Atomic force microscopy, X-ray diffraction, Dynamic light scattering, UV-Vis spectrophotometer.	**7**
6.	**Applications of nanotechnology in chemical industry:** Catalysis, fuel cells, drug delivery and diagnostics, coatings, nanocomposites polymers, fluid inks, dyes	**6**

	paints, cosmetics and consumer goods , nano sensor , water treatment and the environment, food and agriculture, applications of block copolymers, dendrimers, carbon nanotubes.	

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
20	30	30	20	-	-

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Textbooks:

1. C.N.R Rao, Achim Müller, A. K. Cheetham, The Chemistry of Nanomaterials: Synthesis, Properties and Applications, Wiley, 2004.
2. B.S. Murty, P. Shankar, Baldev Raj, B.B Rath and James Murday, Textbook of Nanoscience and Nanotechnology, University Press, 2012.

Reference Books:

1. M. A. Ratner and D. Ratner, Nanotechnology, Pearson, 2003.
2. G. Cao, Nanostructures and Nanomaterials: Synthesis, Properties and Applications, Imperial College Press, 2004.
3. Poorvi Dutta & Sushmita Gupta, Understanding of Nano Science and Technology, Global Vision Publishing House, 2006.

Course Outcomes:

After learning this course, students will be able to:

Sr. No.	CO statement
CO-1	Describe nanoscience and technology in different fields.
CO-2	Understand the properties and synthesis methods of nanomaterials.
CO-3	Explain methods of nanomaterial synthesis and fabrication.
CO-4	Illustrate different types of nanomaterials.
CO-5	Understand characterization techniques for nanomaterials.
CO-6	Describe application of nanotechnology in chemical industry.

List of Open Source Software/learning website:

- https://nptel.ac.in/courses/103101141

Bachelor of Engineering
Subject Code: CH2320
Subject Name: Sustainable Technology

Shroff S.R. Rotary Institute of Chemical Technology

Semester: VI

Type of course: Open Elective-IV

Prerequisite: Basics of Heat Transfer, Mass Transfer, and Fluid Flow Operations.

Rationale: Technologies are essential for manufacturing different chemical products. Use of sustainable technologies such as Zero waste concept. Environmental impact assessment, sustainable habitat, Green buildings, green materials, Energy, Conventional and renewable sources, etc.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	1	0	4	70	30	30	20	150

Content:

Sr. No	Content	Total Hrs.
	SECTION-A	
1.	**Introduction:** Need and concept of sustainability, social environmental and economics sustainability concepts, sustainable development, nexus between technology and sustainable development, challenges for sustainable development, multilateral environmental agreements and protocols - clean development mechanism (CDM), Environmental legislation in India - Water Act, Air Act.	**6**
2.	**Air, Water, and Solid Pollution:** Effect of air pollution, water pollution-sources, sustainable wastewater treatment, solid waste - sources, impacts of solid waste, zero waste concept, 5R concept, global environmental issues - resource degradation, climate change, global warming, ozone layer depletion, regional and local environmental issues, carbon credits and carbon trading, carbon foot print.	**6**
3.	**Environmental Management Standards:** ISO 14000 series, life cycle analysis (LCA) -scope and goal, bio-mimicking, environment impact assessment (EIA) - procedure of EIA in India.	**6**
	SECTION-B	
4.	**Introduction to Sustainability:** Sustainable habitat, green buildings, green materials for building construction, material selection for sustainable design, green buildings certification, method for increasing energy efficiency of buildings, sustainable cities, sustainable transport.	**7**
5.	**Energy Sources:** basic concepts of conventional and non-conventional, solar energy, fuel cells, wind energy, small hydro plants, bio-fuels, energy derived from	**6**

	oceans, geothermal energy.	
6.	**Green Engineering, Sustainable Urbanization, Industrialization and Poverty Reduction:** Social and technological change, industrial process: material selection, pollution prevention, industrial ecology, industrial symbiosis.	**5**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
25	30	25	20	-	-

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E:Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Textbooks:

1. A. S Bradley, A. O. Adebayo, P. Maria, Engineering application in sustainable design and development, 1st Edition, CL Engineering, 2015.

Reference Books:

1. D. T. Allen and D. R. Shonnard, Sustainability Engineering: Concepts, Design and Case Studies, 1st edition, Prentice Hall, 2011.
2. Environment Impact Assessment Guidelines, Notification of Government of India, 2006.
3. K. M. Mackenthun, Basic Concepts in environmental Management, 1st edition, Lewis Publication London, 1998.

List of Tutorials:

Sr. No.	**Exercise**	**Approx. Hours required**
1.	Identify of sustainability in your neighbourhood in education, housing, water resources, energy resources, energy sources, food supplies, environment protection etc.	1
2.	Identify the threats for sustainability in any selected area and explore solutions for the same.	1
3.	Assess the pollution status of a small area.	1
4.	Identify programmes for enhancing public environmental awareness.	1
5.	List down different measures that can be adopted for pond conservation.	1
6.	Conduct life cycle analysis of products polyvinyl carbonate bottle.	1

7.	Conduct an environment impact assessment.	1
8.	Discuss the design aspects of a sustainable building for your campus.	1
9.	Find out the energy saving that can be achieved by the installation of a solar water heater.	1
10.	Find out the carbon credits you can gain by using a sustainable transport system.	1

Course Outcomes:

After learning this course, students will be able to:

Sr. No.	CO statement
CO-1	Understand need and concepts of sustainable technology.
CO-2	Relate effect of reduction of air and water pollution with sustainable development.
CO-3	Discuss environmental management standards for sustainable development.
CO-4	Establish a clear understandings of the role of sustainable habitat.
CO-5	Apply renewable energy sources to save environment.
CO-6	Know the methods, tools, and incentive for sustainable development.

List of Open Source Software/learning website:

- https://nptel.ac.in/

Shroff S.R. Rotary Institute of Chemical Technology

Type of course: Work-Personality Development

Prerequisite: To keep open mind and will to learn humanity for oneself and society.

Rationale: The Contributor Program aims to accomplish the following outcomes in the lives of students–

- Improve the employability of students by giving them the right work ethic and thinking that employers are looking for.
- Build their confidence with which they can go into any job and contribute meaningfully.
- Improve their ability to engage better in the workplace and to be able to handle the challenges that come up there.
- Build their career-worthiness and help them develop into future-ready contributors with ability to navigate a career in a volatile, changing world.
- Widen their choices of career and success, so that they are able to open up more opportunities for themselves and take up unconventional career pathways.
- Enable them to recognize how they, as technical professionals, can participate and make a positive contribution to their communities and to their state.

Towards this goal, the Contributor Program has been designed to awaken and strengthen students from within, in terms of building positive self-esteem, increasing their confidence level and I-can attitude, improving their aspirations, giving them new methods of thinking, building their cognitive capacities, exposing them to the skills and practices associated with being contributors in the workplace (not mere employees).

The Program content is also designed to expose students to real-world workplace scenarios and sensitize them to some of the challenges faced in society around them, especially in the local communities around them and in their own state of Gujarat.

The Contributor Program syllabus has been evolved and fine-tuned over several years, (a) to address the changing need and contemporary challenges being faced by industry and what employers of today are looking for in the people they hire and (b) by working extensively with universities and students building an appreciation of their challenges and concerns. At the core, the program is guided by the higher ideas and principles of practical Vedanta in work.

Bachelor of Engineering
Subject Code: MH2302
Subject Name: Contributor Personality Development Program – II

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
1	1	0	2	50	30	00	20	100

Content:

Sr. No.	Content	Total Hrs.
	SECTION-A	
1	**Finding Solutions** The market environment in which organizations are operating, is becoming increasingly dynamic and uncertain. So, employers are increasingly seeking out people who can innovate and figure out solutions in the face of any challenge (unlike in the past when it was the people who were most efficient and productive, who were valued by organizations). At the heart of innovation lies this way of thinking of "finding solutions" rather than "seeing problems or roadblocks". Students learn how to build this way of thinking, in this topic.	04 hrs Classroom engagement (including self-discovery/ solutioning sessions)
2	**Creating Value** Companies are also looking for employees who do not just work hard, or work efficiently or productively - but those who will make a valuable difference to the fortunes of the company. This difference may come from innovation, but it may also come from focusing on the right things and identifying what really matters – both to the company and to the customers. In this topic, students learn how to build this capability.	04 hrs Classroom engagement (including self-discovery/ solutioning sessions)

3	**Engaging deeply** The environment we live in is becoming increasingly complex because more and more things are getting interconnected, new fields are emerging, technologies are rapidly changing, capabilities and knowledge one is trained in will become fast obsolete. In such a scenario, the student's ability to quickly understand and master what is going on, dive deep, get involved in any area, rapidly learn new capabilities that a job demands, is important. Engaging deeply is a core way of thinking that can help them in this. In this topic, students learn how to engage deeply.	04 hrs Classroom engagement (including self-discovery/ solutioning sessions)
SECTION-B		
4	**Enlightened self-interest & collaboration at work** The changing nature of work in organizations and in the global environment is increasingly demanding that people work more collaboratively towards shared goals and more sustainable goals. A key to working successfully when multiple stakeholders are involved is "thinking in enlightened self-interest". In this topic, students learn how to develop this way of thinking (going beyond "narrow self-interest").	04 hrs Classroom engagement (including self-discovery/ solutioning sessions)
5	**Human-centered thinking & Empathy** In this topic, students explore a human-centric approach to work – where the ability to recognize and respond to other people (whether they are users or customers or team members) as a human being with human needs and difficulties, is essential. This is at the heart of user-centric design of products and solutions, at the heart of genuine customer- centricity in services, and of any successful interaction with other people.	04 hrs Classroom engagement (including self-discovery/ solutioning sessions)
6	**Trust Conduct** The biggest currency in a sustainable career is "trust" i.e. being trusted by team members, bosses, and customers. When we are trusted, people listen to us, they are willing to give us the chance to grow, give us the space to make	04 hrs Classroom engagement (including self-discovery/ solutioning sessions)

	mistakes, and work seamlessly with each other without always having to "prove ourselves". In this topic, students learn how to demonstrate conduct that builds the trust of people.	

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
-	**20**	**20**	**20**	**20**	**20**

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate
C: Create and above Levels (Revised Bloom's Taxonomy)

Reference resources:

A. Basic reference for both students and teachers

1. Contributor Personality Program textbook cum workbook developed by Illumine
2. Web-based ActivGuide™ for self-exploration of rich media resources to vividly understand many of the ideas, watch role models, learn from industry people, get reference readings – that help them enrich the understanding they gained in the class published by Illumine Foundation

B. Advanced reference for teachers

1. On Contributors, Srinivas V.; Illumine Ideas, 2011
2. Enlightened Citizenship and Democracy; Swami Ranganathananda, Bharatiya Vidya Bhavan, 1989
3. Eternal Values for a Changing Society – Vol I-IV, Swami Ranganathananda; Bharatiya Vidya Bhavan
4. Karma Yoga, Swami Vivekananda; Advaita Ashrama
5. Vivekananda: His Call to the Nation, Swami Vivekananda; Advaita Ashrama
6. Six Pillars of Self Esteem, Nathaniel Branden; Bantam, 1995
7. Mindset: The New Psychology of Success, Carol S. Dweck; Random House Publishing Group, 2007
8. Lasting Contribution: How to Think, Plan, and Act to Accomplish Meaningful Work, Tad Waddington; Agate Publishing, 2007

9. Why not?: how to use everyday ingenuity to solve problems big and small, Barry Nalebuff, Ian Ayres; Harvard Business School Press, 2003
10. The value mindset: returning to the first principles of capitalist enterprise (Ch 8 & 9); Erik Stern, Mike Hutchinson; John Wiley and Sons, 2004
11. The Power of Full Engagement: Managing Energy, Not Time, is the Key to High Performance and Personal Renewal, Jim Loehr, Tony Schwartz; Simon and Schuster, 2003
12. Creating Shared Value, Michael E. Porter and Mark R. Kramer; Harvard Business Review; Jan/Feb2011, Vol. 89 Issue 1/2
13. The Speed of Trust: The One Thing That Changes Everything, Stephen M. R. Covey, Rebecca R. Merrill, Stephen R. Covey; Free Press, 2008
14. The Courage to Meet the Demands of Reality, Henry Cloud; HarperCollins, 2009
15. Responsibility at work: how leading professionals act (or don't act) responsibly, Howard Gardner; John Wiley & Sons, 2007

Course Outcomes:

Students will be able to:

Sr. No.	CO statement
CO-1	Students will be able to recognize & appreciate the thinking required to find solutions in the face of any challenge.
CO-2	Students will be able to recognize & appreciate different types of value that can be created and the different ways to create value for others.
CO-3	Students will be able to recognize & appreciate how to engage deeply, and its need, value, payoffs and consequences in different contexts.
CO-4	Students will be able to differentiate between 'enlightened self-interest' and 'narrow self-interest' & appreciate the payoffs/ consequences of both when working with multiple stakeholders.
CO-5	Students will be able to recognize & appreciate the human side of situations or interactions or projects that will help them develop a more human-centric approach/ response to work.
CO-6	Students will be able to recognize & appreciate conduct which builds trust of people in contrast to conduct which breaks trust of people - in teams / organization & the value of trust conduct in various situations.

Prepared By: Ms. Aakancha Sanjeev Kumar

Moderated By: Dr. Purvi Naik.