DEPARTMENT OF CHEMICAL ENGINEERING

B.Tech

Chemical Engineering

CURRICULUM

&

SYLLABUS

2021 REGULATION

KALASALINGAM ACADEMY OF RESEARCH AND EDUCATION

(DEEMED TO BE UNIVERSITY)

ANANDNAGAR, KRISHNANKOIL-626126

Curriculum Framework - Chemical Engineering

Environment/ Indian Constitution	**44**	**Foundation Core**	**Mathematics and Sciences**
			Engineering Sciences
			Computing
			Sustainable Product Development
			Human Values and communication
			Entrepreneurship and Innovation
	16	**University Elective**	Engineering (outside school)
			Liberal arts (or) Mathematics and Sciences
Complementary Skills	**52**	**Program Core**	
	24	**Program Elective**	
	16	**Experiential Core**	Design Project
			Capstone
	8	**Experiential Elective**	CSP/ Internship/ UG Research/ Competitions
Total	**160**		

Program Core

S. No.	Course Code	Course Name	Course Type	L	T	P	X	C	Prerequisite
1.	212CHE1101	Chemical Process Calculations	T	2	1	0	0	3	NA
2.	212CHE1102	Chemical Technology	T	2	1	0	0	3	NA
3.	212CHE1103	Chemical Engineering Thermodynamics	T	2	1	0	0	3	NA
4.	212CHE1301	Particulate Science and Technology	ICT	2	1	2	0	4	NA
5.	212CHE1302	Fluid Mechanics	ICT	2	1	2	0	4	NA
6.	212CHE1303	Heat Transfer	ICT	2	1	2	0	4	NA
7.	212CHE2101	Mass Transfer I	T	2	1	0	2	3	M1
8.	212CHE2301	Mass Transfer II	ICT	2	1	2	0	4	Mass Transfer I
9.	212CHE2302	Chemical Reaction Engineering	ICT	2	1	2	0	4	M1
10.	212CHE3301	Process Equipment Design Drawing	ICT	2	1	0	2	4	Heat and Mass Transfer, CRE
11.	212CHE3302	Process Dynamics and Control	ICT	3	0	2	0	4	PDE, Transforms
12.	212CHE3303	Process Modeling and	ICT	2	1	0	0	3	M1

		Simulation							
13.	212CHE3101	Transport Phenomena	T	2	1	0	0	3	Fluid Mechanics
14.	212CHE1104	Partial Differential Equations and Transforms	T	2	1	0	0	3	NA
15.	212CHE1105	Engineering Mechanics	T	2	1	0	0	3	NA

*PDE – Partial differential equations

Program Elective

S. No.	**Course Code**	**Course Name**	**Course Type**	**L**	**T**	**P**	**C**	**Prerequisite**
1.	213CHE2101	Heterogeneous Catalysis	T	3	0	0	3	CET
2.	213CHE1101	Polymer Science and Technology	T	3	0	0	3	NA
3.	213CHE1102	Interfacial Science and Engineering	T	3	0	0	3	NA
4.	213CHE2102	Process Utilities and pipeline design	T	3	0	0	3	PEDD
5.	213CHE2103	Boundary Layer Theory	T	3	0	0	3	Fluid Mechanics
6.	213CHE1103	Nano science and technology	T	3	0	0	3	NA
7.	213CHE1104	Green Technology	T	3	0	0	3	NA
8.	213CHE1105	Petroleum Refinery Engineering	T	3	0	0	3	NA
9.	213CHE1106	Process Instrumentation	T	3	0	0	3	NA
10.	213CHE1107	Colloids and Surface Science	T	3	0	0	3	NA
11.	213CHE2104	Multiphase Flow	T	3	0	0	3	Fluid Mechanics
12.	213CHE2105	Computer Aided Process Plant Design	TP	3	0	0	3	PEDD
13.	213CHE1108	Fertilizer Technology for Chemical Engineers	TP	3	0	0	3	NA
14.	213CHE1109	Environmental Engineering	T	3	0	0	3	NA
15.	213CHE1110	Chemical Process in Pulp and Paper Technology	TP	3	0	0	3	NA
16.	213CHE1111	Electrochemical Engineering	TP	3	0	0	3	NA
17.	213CHE1112	Chemical Process Plant Safety	T	3	0	0	3	NA
18.	213CHE2106	Design of Multicomponent Separation Processes	T	3	0	0	3	Mass Transfer I

19.	213CHE1113	Fundamentals of Computational Fluid Dynamics	T	3	0	0	3	NA
20.	213CHE1114	Bioprocessing and Bioseparations	T	3	0	0	3	NA
21.	213CHE1115	Membrane Science and Engineering	T	3	0	0	3	NA
22.	213CHE1116	Electrochemical Conversion and Storage Devices	T	3	0	0	3	NA
23.	213CHE1117	Hydrogen Energy and Fuel Cell Technology	T	3	0	0	3	NA
24.	213CHE1118	Air Pollution Control Engineering	T	3	0	0	3	NA
25.	213CHE1119	Fine Chemical Technology	T	3	0	0	3	NA
26.	213CHE1120	Materials Technology	T	3	0	0	3	NA
27.	213CHE1121	Process Engineering Economics	T					NA

*****CET – Chemical Engineering Thermodynamics

*PEDD - Process Equipment Design Drawing

University Elective

S. No.	Course Code	Course Name	Course Type	L	T	P	C	Prerequisite
1.	214CHE1101	Corrosion Science and Engineering	T	3	0	0	3	NA
2.	214CHE1102	Separation Techniques	T	3	0	0	3	NA
3.	214CHE1103	Fertilizer Technology	T	3	0	0	3	NA
4.	214CHE1104	Membrane Science and Technology	T	3	0	0	3	NA
5.	214CHE1105	Process Industrial Safety	T	3	0	0	3	NA
6.	214CHE1106	Fuel and Combustion Engineering	T	3	0	0	3	NA
7.	214CHE1107	Pulp and Paper Technology	T	3	0	0	3	NA
8.	214CHE1108	Treatment of Industrial Effluents	T	3	0	0	3	NA
9.	214CHE1109	Coal Processing Technology	T	3	0	0	3	NA
10.	214CHE1110	Batteries and Fuel Cells	T	3	0	0	3	NA
11.	214CHE1111	Drugs and Pharmaceuticals Technology	T	3	0	0	3	NA
12.	214CHE1112	Polymer Science and	T	3	0	0	3	NA

		Technology						
13.	214CHE1113	Pharmaceutical Engineering	T	3	0	0	3	NA
14.	214CHE1114	Disaster Management in Chemical Industries	T	3	0	0	3	NA
15.	214CHE1115	Photonics and Optoelectronic Devices	T	3	0	0	3	NA

Minors

S. No.	Course Code	Course Name	Course Type	L	T	P	C	Prerequisite
1.	217CHE2101	Chemical Process Calculations	T	3	1	0	4	NA
2.	217CHE2102	Transfer Operations I	T	3	1	0	4	NA
3.	217CHE2101	Transfer Operations II	T	3	1	0	4	Transfer Operations I
4.	217CHE2102	Chemical Reaction Engineering	T	3	1	0	4	NA
5.	217CHE2103	Chemical Technology	T	3	0	1	4	NA

Honors

S. No.	Course Code	Course Name	Course Type	L	T	P	C	Prerequisite
1.	218CHE2101	Advanced Chemical Engineering Thermodynamics	T	3	0	0	3	CET
2.	218CHE2102	Advanced Heat Transfer	T	3	0	0	3	Heat Transfer
3.	218CHE2103	Advanced Transport Phenomena	T	3	0	0	3	Fluid Mechanics
4.	218CHE2104	Process Safety Management	T	3	0	0	3	NA
5.	218CHE2105	Fluidization Engineering	T	3	0	0	3	Fluid Mechanics
6.	218CHE2106	Biochemical Engineering	T	3	0	0	3	CRE
7.	218CHE2107	Environmental Impact Assessment	T	3	0	0	2	NA

*****CET – Chemical Engineering Thermodynamics

*CRE – Chemical Reaction Engineering

Program Core Courses

212CHE1101	Chemical Process Calculations	L	T	P	C
		2	1	0	3
Prerequisite: Nil	**Course Category:** Program Core **Course Type:** Theory				

Course Objective(s):

To develop systematic problem solving skills, to learn what material balance and energy balance are, how to formulate, apply and solve them and to learn how to deal with the complex process problems.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Describe the fundamentals of stoichiometry

CO2: Apply material balances on unit operations and processes

CO3: Evaluate humidity with/without the use of psychometric chart

CO4: Apply Energy balance to unit operations and processes

CO5: Apply Energy and Material balance to industrial processes

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H	M										
CO2	H	H										
CO3		H										
CO4	H	H										
CO5	H	M						L	L	L		

UNIT 1: Introduction **9 Hours**

Units and dimensions and conversions - Mass and volume relations -Stoichiometric and Composition relations, Degree of completion - Ideal gas law, Dalton's Law, Amagat’s Law, Average molecular weight of gaseous mixtures - Vapor Pressure, Effect of temperature on vapor pressure, Vapor pressure plot- Clasius-Clapeyron equation, Cox Chart, Duhring’s Plot Raoult's Law.

UNIT 2: Material Balance 9 Hours

Material balance without chemical reaction Drying, Mixing, Crystallization, Extraction, Absorption, Distillation and evaporation, Analysis of system with bypass, Recycle and purging, Psychometric, Humidification and dehumidification. Steady state and unsteady state material balances Material balances for systems with and without chemical reactions – Material balance applied to different unit operations- Analysis of systems with by-pass, recycle, and aid of computers in solving material balance problems.

UNIT 3: Humidity and saturation 9 Hours

Material balance with chemical reaction Principles of Stoichiometry, Concept of limiting, Excess reactants and Inert, Fractional and Percentage conversion, Fractional yield and Percentage yield, Selectivity, related problems. Relative and Percent saturation - Dew point - Dry and Wet bulb temperatures - Use of humidity charts for engineering calculations

UNIT 4: Energy Balance 9 Hours

Heat capacity of gases, liquids and solutions - Heat of fusion and vaporization - Steady state energy balance for systems with and without chemical reactions - Calculations and application of heat of reaction, Combustion, Formation, Neutralization - Calculation and application of heat of solution, Enthalpy concentration chart, Calculation of theoretical and actual flame temperature.

UNIT 5: Applications of Material and Energy Balances 9 Hours

Applications of material and energy balances to various process industries especially combustion of solids, liquids and gaseous fuels.

Total: 45 Hours

Textbook(s):

1. B. I. Bhatt, and S. M. Vora, Stoichiometry - Tata McGraw-Hill Publishing Company, New Delhi, 2010 (5^{th} Edition)

2. P. M. Doran, Bioprocess Engineering Principles- Academic Press (An Imprint of Elsevier), New Delhi, 2012 (2^{nd} Edition)

Reference(s):

1. D.M. Himmelblau, Basic Principles and Calculations in Chemical Engineering- Prentice-Hall of India, New Delhi, 2012 (8^{th} Edition).

2. N. Bruce, Handbook of Chemical Reactor Design Optimization and Scale up - McGraw Hill New York, 2002.

212CHE1102	Chemical Technology	L	T	P	C
		2	1	0	3
Prerequisite: Nil	**Course Category:** Program Core **Course Type:** Theory				

Course Objective(s):

To understand the basic process of chemical Engineering and its applications in various aspects.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Explain the processing of natural products

CO2: Describe about microbial processes and edible oil refining process

CO3: Enumerate the manufacturing processes of chloro-alkali and sulfur chemicals

CO4: Explain the manufacturing processes of industrial gases, petro and silicate chemicals

CO5: Describe the manufacturing processes of fertilizer and agrochemicals

Mapping of course outcomes:

CO/PO	PO											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
CO1	H		M				L					
CO2					M						M	
CO3		H						L				
CO4					H					L		
CO5			H			M						L

UNIT 1: Natural Products Processing **9 Hours**

Production of pulp, paper and rayon, Manufacture of sugar, starch and starch derivatives, Gasification of coal and chemicals from coal.

UNIT 2: Fermentation & Edible Oil Refining Processes **9 Hours**

Industrial microbial processes: Fermentation processes for the production of ethyl alcohol, citric acid and antibiotics, Edible oil refining processes: Refining of edible oils and fats, fatty acids, Soaps and detergents.

UNIT 3: Chloro-Alkali & Sulfur Industries **9 Hours**

Alkalis and Acids: Chloro - alkali Industries: Manufacture of Soda ash, Manufacture of caustic soda, chlorine, and common salt, Mining of sulphur, Manufacture of Sulphur, Sulphuric acid and Hydrochloric acid.

UNIT 4: Industrial Gases, Petrochemical & Silicate Industries 9 Hours

Industrial gases: Oxygen, Nitrogen, and Hydrogen - Basic block diagram and simplified process flow diagram for manufacture of Petrochemicals: C1, C2, C3, C4, benzene, toluene, xylene - Silicate industry: Portland cement, Glasses, Ceramics.

UNIT 5: Fertilizers and Agrochemical Industries 9 Hours

Fertilizers: Nitrogen Fertilizers; Synthetic ammonia, nitric acid, Urea, Phosphorous Fertilizers: Phosphate rock, phosphoric acid, super phosphate and Triple Super phosphate.

Total: 45 Hours

Textbook(s):

1. George T. Austin, Shreve's Chemical Process Industries - McGraw-Hill International, Singapore, 2017 (5^{th} Edition)

2. M. Gopala Rao and Marshall Sittig - Dryden's Outlines of Chemical Technology - East-West Pvt Ltd., New Delhi, 1997 (3^{rd} Edition)

Reference(s):

1. J. A. Kent, Kent and Riegel's Handbook of Industrial Chemistry and Biotechnology – Springer Netherlands, 2007 (11^{th} Edition)

2. M. Farhat Ali and Bassam El Ali - Handbook of Industrial Chemistry: Organic Chemicals – McGraw Hill, New York, 2004 (1^{st} Edition)

3. G. N. Pandey, Textbook of Chemical Technology - Vol. I & II, Vikas Publishing House, New Delhi, 2018 (2^{nd} Edition)

212CHE1103 Chemical Engineering Thermodynamics	L	T	P	C
	2	1	0	3

Prerequisite: Nil **Course Category:** Program Core

Course Type: Theory

Course Objective(s):

To understand the basic principles and application of first and second law of thermodynamics, and phase equilibria.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Apply mass and energy balances to open systems

CO2: Evaluate the properties of non-ideal gases

CO3: Apply second law of Thermodynamics

CO4: Explain the thermodynamic Relations

CO5: Solve problems involving liquefaction, refrigeration and different power cycles.

Mapping of course outcomes:

CO/PO	PO											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
CO1	H	H		M						M		
CO2	H	M						H				L
CO3			H	H				M				
CO4				H				M	H		L	
CO5					H					M		

UNIT 1: Introduction **9 Hours**

Scope of thermodynamics, Dimensions and Units, Temperature, Pressure, Work, Energy, Heat, Energy conservation & First law of thermodynamics, State functions, Equilibrium, Phase Rule, Reversible process, Constant P, V, T processes, Mass and energy balances for open systems.

UNIT 2: PVT Behavior & Phase Transitions **9 Hours**

Ideal gas law, Van der Waals, Viral and Cubic equations of state; Reduced conditions & Corresponding states theories; correlations in description of material properties and behavior, Heat effects-latent heat, sensible heat, standard heats of formation, reaction and combustion.

UNIT 3: Second Law of Thermodynamics **9 Hours**

Statements of the second law, Heat engines, Carnot's theorem, Thermodynamic Temperature Scales, Entropy, Entropy changes of an ideal gas, Mathematical statement of the second law, Entropy balance for open systems, Calculation of ideal work, and Lost work.

UNIT 4: Thermodynamic Relations 9 Hours

Thermodynamic relations, Maxwell's relations, Jacobian algebra, Estimation of thermodynamic properties.

UNIT 5: Phase Equilibria with solution thermodynamics 9 Hours

Phase equilibria, Pure component and mixtures, Latent heat correlation, Van Laar, Margules equations, Gibbs-Duhem's equation, Consistency tests, Partially miscible and immiscible systems - Azeotropes - Retrograde condensation - Thermodynamic diagrams.

Total: 45 Hours

Textbook(s):

1. J. M. Smith H. C. Van Ness, M. M. Abbot, and B. Bhatt, Introduction to Chemical Engineering Thermodynamics - McGraw Hill, New York, 2009 (8^{th} Edition)

2. Paul Stevenson, Thermodynamics for Chemical Engineering: A Process Approach - CRC Press, Taylor & Francis Group, 2019 (1^{st} Edition)

3. J. R. Elliot, and C. T. Lira, Introductory Chemical Engineering Thermodynamics - Pearson Education India, 2013 (2^{nd} Edition)

Reference(s):

1. M. J. Moran, H. N. Shapiro, D. D. Boettner and M B Bailey, Principles of Engineering Thermodynamics - Wiley Publications, 2015 (8^{th} Edition)

2. P. K. Nag, Engineering Thermodynamics - McGraw Hill, New York, 2017 (6^{th} Edition)

3. Y. A. Cengel, M. A. Boles, and M. Kanoglu. Thermodynamics - An Engineering Approach - McGraw Hill, New York, 2019 (9^{th} Edition)

212CHE1301	Particulate Science and Technology	L	T	P	C
		2	1	2	4

Prerequisite: Nil

Course Category: Program Core

Course Type: Integrated Course

Course Objective(s):

To understand the characterization of Particulate Material, their synthesis and handling.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Characterize the particles

CO2: Understand the principle of size reduction and synthesis methods

CO3: Illustrate various sedimentation and separation techniques

CO4: Explain various types of filtration, mixing and kneading

CO5: Identify the conveyors suitable for particular operation

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H											
CO2	H	H		M	M							
CO3	M			M	H							
CO4	H		M	H					L	L		
CO5			H									

UNIT 1: Introduction **9 Hours**

Characteristics of Particulate Material: Properties and characterization of particulate solids, analysis and technical methods for size and surface area distribution of powder.

UNIT 2: Size Reduction and Synthesis Methods **9 Hours**

Principles of size reduction - Specific properties of solids for size reduction - Energy required for size reduction - Crushing and grinding efficiency - Laws of crushing - Classification of crushing and grinding equipment - Construction and working principle of mostly used equipment, Computer simulation techniques for mill performance, Introduction to synthesis of composite material by spray technique, Aerosol generation.

UNIT 3: Sedimentation and Separation **9 Hours**

Free Settling, hindered settling, design of settling tanks Mechanical classification and Classifiers - Rare and dense medium separation - Magnetic separation - Electrostatic separation - Centrifugal separation - Electrostatic precipitators - Impingement separators - Gas solids separation - Cyclone separators - Bag filters - Scrubbers Fluidization - Encapsulation.

UNIT 4: Mixing, Blending and Filtration 9 Hours

Mixing of solids, blending, kneading - Power for agitation - Correlations for power consumption - Filtration- Batch and continuous filtration, compressible and incompressible filter cakes- Calculations for specific cake resistance, filter medium resistance - Industrial filters - Centrifugal filtration.

UNIT 5: Conveying 9 Hours

Handling of Particulate Material: Conveying methods - Selection of conveyors - Transport of fluid solid systems - Pneumatic and Hydraulic Conveying, Storage methods and design of silo.

Total: 45 Hours

List of experiments:

1. Studies in an agitated vessel.

2. Drag studies

3. Particle size distribution

4. Screening Efficiency

5. Determination of specific surface area by air elutriation

6. Determination of area of a thickener by batch sedimentation test.

7. Size reduction using Jaw Crusher and Verification of crushing laws.

8. Size reduction using Ball Mill and determination of specific surface area.

9. Drop weight crushing and verification of crushing laws.

10. Determination of specific cake resistance and filter medium resistance for leaf filtration

11. Determination of specific cake resistance and filter medium resistance for rotary vacuum

12. Determination of specific cake resistance and filter medium resistance for filtration in a plate and frame filter press.

Textbook(s):

1. W. L. McCabe, J. C. Smith, and P. Harriot, Unit Operation of Chemical Engineering -- McGraw Hill, New York, 2004 (6th Edition).

2. C. J. Geankopolis, Transport Processes and Separation Process Principles (Includes Unit Operations), Prentice Hall of India, New Delhi, 2003 (4^{th} Edition).

Reference(s):

1. J. H. Harker, J. F. Richardson, J. M. Coulson, and R. P. Chhabra, Coulson and Richardson's Chemical Engineering Volume I - Butterworth-Heinemann - 1999 (6^{th} Edition)

2. J. H. Harker, J. R. Backhurst, J. F. Richardson, and J. M. Coulson, Coulson and Richardson's Chemical Engineering Volume II - Butterworth-Heinemann - 2002 (5^{th} Edition)

3. W. L. Badge, and J. T. Banchero, Introduction to Chemical Engineering- Tata McGraw Hill, New Delhi, 1997 (1^{st} edition)

212CHE1302	Fluid Mechanics	L	T	P	C
		2	1	2	4
Prerequisite: Nil	**Course Category:** Program Core **Course Type:** Integrated Course				

Course Objective(s):

To understand the basic principles of fluid flow in pipes and momentum balance.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Explain the basic principles of fluid statistics.

CO2: Analyze fluid flow problems by applying the momentum and energy equations.

CO3: Analyze system and control volume approaches of pipe flows.

CO4: Analyze flow past immersed objects.

CO5: Analyze fluid Transportation and Computational methods.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H	L						M				
CO2	M	L					H		M			M
CO3	H	L			H					L		
CO4			H		M						M	
CO5		H					H		L		M	

UNIT 1: Fluid Statistics **12 Hours**

Properties of fluids - Types of fluids - Newtonian and non-Newtonian fluids -Fluid statics – Classification of fluid motion- concept of pressure- -Pressure Measurement and application – Continuity Equation-Equation of motion- and Navier stokes Equation. Dimensionless numbers, Dimensional analysis- Similarity.

UNIT 2: Mass and Momentum Balances **12 Hours**

Mass and momentum balances, Kinematics of fluid flow, stream line, stream tube, velocity potential, Time dependent fluids, Reynolds number, experiment and significance - Momentum balance - Potential flow - Euler's equation of motion- Bernoulli's equation.

UNIT 3: System and Control Volume Approaches **12 Hours**

Reynolds transport theorem, Flow of incompressible fluids in pipes turbulent flow through closed conduits, velocity profile and friction factor for smooth and rough pipes - Head loss due to friction in pipes, Fitting, Moody diagram.

UNIT 4: Flow past Immersed Objects **12 Hours**

Flow of fluids through solids - Form drag - Skin drag - Drag coefficient - Flow around solids and packed beds, Friction factor for packed beds, Ergun's Equation - Motion of particles through fluids - Motion under gravitational and centrifugal fields - Terminal settling velocity - Fluidization, mechanism, types, general properties and applications.

UNIT 5: Transportation and Computational methods **12 Hours**

Transportation and metering - Measurement of fluid flow, Orifice meter, Venturi meter, Pitot tube, Rotameter, Weirs and Notches - Transportation of fluids, Positive displacement pumps, Rotary pumps - Reciprocating pumps - Centrifugal pumps and characteristics - Computational methods in fluid flow, Comparison of CFD methodologies.

Total: 60 Hours

LIST OF EXPERIMENTS

1. Experiment to determine pipe friction
2. Experiment to determine friction for flow in helical coil
3. Experiment to determine friction for flow in an annulus
4. Flow through fittings/valves
5. Flow through non-circular conduits.
6. Calibration of Rotameter
7. Determination of coefficient of discharge of an orifice meter
8. Determination of coefficient of discharge venturi meter
9. Flow through open orifice/weirs and notches
10. Performance curves for a centrifugal pump
11. Performance curves for a Reciprocating pump
12. Experiment to determine friction in Packed Bed
13. Determination of minimum fluidization velocity in a fluidized bed

Textbook(s):

1. Noel de Nevers, Fluid Mechanics for Chemical Engineers, McGraw Hill, New York, 1991 (2^{nd} Edition).

2. W. L. McCabe, J. C. Smith, and P. Harriot, Unit Operation of Chemical Engineering, McGraw Hill, New York, 2005 (7th Edition).

3. B. R. Munson, and D. F. Young, T. H. Okiishi, Fundamentals of Fluid Mechanics, Wiley Publications, 2006 (5th Edition).

4. M. White, Fluid Mechanics, Tata McGraw Hill, New Delhi, 2016 (8th Edition).

5. V. Gupta and S. K. Gupta, Fundamentals of Fluid Mechanics, New Age International, 2011 (2nd Edition).

Reference(s):

1. R. L. Panton, Incompressible Flow, Wiley Publications, 2005 (3rd Edition).

2. R. B. Bird, W. E. Stewart, and E. N. Lightfoot, Transport Phenomena - Wiley Publications, 2007 (Revised 2nd Edition).

3. J. H. Harker, J. F. Richardson, J. M. Coulson, and R. P. Chhabra, Coulson and Richardson's Chemical Engineering Series Volume I - Butterworth-Heinemann - 1999 (6th Edition)

212CHE1303	Heat Transfer	L	T	P	C
		2	1	2	4

Prerequisite: Nil

Course Category: Program Core

Course Type: Integrated Course

Course Objective(s):

To study the heat transfer basic functions through convection, conduction and radiation modes and apply the understanding to design heat exchangers.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Analyze and apply the heat conduction

CO2: Analyze and apply the heat convection

CO3: Analyze and apply the radiation

CO4: Explain the concepts of heat transfer with phase change

CO5: Analyze and apply the heat exchanger without phase change

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H	L	M									
CO2	H	H	L	H	M							L
CO3	H	H	L	H	M						L	
CO4	H	H	L	H	M							
CO5		L	L	H					H	M	M	

UNIT 1: Conduction **12 Hours**

Importance of heat transfer in Chemical Engineering operations - Modes of heat transfer - Fourier's law of heat conduction, Governing equation in Cartesian, cylindrical and spherical coordinates. One dimensional steady state heat conduction with and without heat generation. Composite wall, electrical analogy, critical thickness of insulation, heat transfer from extended surface, effect of temperature on conductivity.

UNIT 2: Convection **12 Hours**

Concepts of heat transfer by convection - Natural and forced convection, analogies between transfer of momentum and heat - Reynold's analogy, Prandtl and Coulburn analogy.

Dimensional analysis in heat transfer, Heat transfer coefficient for flow through a pipe, flow past flat plate, Flow through packed beds.

UNIT 3: Radiation **12 Hours**

Basic definitions, concept of black body, laws of black body radiation. Radiation between black surfaces, Radiation heat exchange between grey surfaces. Radiation shielding, Shape factor, Electrical network analogy in thermal radiation systems.

UNIT 4: Heat transfer with phase change **12 Hours**

Boiling of liquids, Pool boiling curve, different types of pool boiling, condensation of vapor. Film wise & drop wise condensation.

UNIT 5: Heat exchanger Without Phase Change **12 Hours**

Heat exchangers, Overall heat transfer coefficient, LMTD and NTU methods of analysis. Design of heat transfer equipment, Double pipe heat exchanger, Shell and tube heat exchanger. Kern's method for design, Bell Delaware Method, Design aspects of finned tube and other compact heat exchangers.

Total: 60 Hours

LIST OF EXPERIMENTS

1. Thermal Conductivity of metal rod
2. Thermal Conductivity of an insulating powder
3. Convective heat transfer (forced and free convection)
4. Transient heat conduction
5. Agitated vessel heat transfer
6. Heat Transfer in Jacketed Kettle
7. Plate Heat Exchanger
8. Double pipe Heat Exchanger
9. Shell and Tube Heat exchanger
10. Vertical and Horizontal Condensers
11. Evaporator
12. Radiation Heat Transfer

Textbook(s):

1. J. P. Holman, Heat Transfer, McGraw Hill, Singapore, 2002 (9th Edition)

2. Donald Q. Kern, Process Heat Transfer, Tata McGraw Hill, New Delhi, 1997 (1st Edition Reprint)

3. Binay K Dutta, Heat Transfer: Principles and Application, PHI Learning Pvt. Ltd., 2000.

4. M. N. Ozisik, Heat Transfer: A Basic Approach, McGraw-Hill, Singapore, 1985

Reference(s):

1. F. P. Incropera, D. P. Dewitt, T. L. Bergman, and A. S. Lavine, Introduction to Heat Transfer, Wiley Publications, Singapore, 2006 (5th Edition).

2. A. Bejan, Convective Heat Transfer, Wiley Publications, Singapore, 2006 (3rd Edition).

3. F. Kreith, R. M. Manglik, and M. S. Bohn, Principles of Heat Transfer, Cengage Learning, 2009 (7th Edition).

212CHE2101	Mass Transfer I	L	T	P	X	C
		2	1	0	3	3

Prerequisite: Nil **Course Category:** Program Core

Course Type: Theory

Course Objective(s):

To understand the calculation of diffusion and the phase differences for a liquid-solid contraction.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Understand and solve diffusion and diffusion related problems

CO2: Estimate mass transfer coefficients for gas–liquid contacting systems and know about various analogies

CO3: Understand the distillation process, able to design the distillation column and able to calculate the number stages of distillation

CO4: Able to solve design problems related to adsorption

CO5: To study about psychrometric apply design calculations of cooling tower

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H	H	M					L				L
CO2		H		H	M					L		
CO3		H	H	H	M		H		M		L	
CO4		H	H	H	M	M						
CO5		L	H	H	M							

UNIT 1: Diffusion **9 Hours**

Molecular and eddy diffusion in gases and liquids - Steady state diffusion under stagnant and laminar flow conditions - Diffusivity measurement and prediction - Multicomponent diffusion - Diffusion in solids and its applications

UNIT 2: Mass transfer coefficients **9 Hours**

Concept of mass transfer coefficients - Mass transfer under laminar and turbulent flow past solids - Boundary layers – Mass transfer at fluids surfaces correlation of mass transfer coefficients - jD - Theories of mass transfer and their applications - Interphase mass transfer and overall mass transfer coefficients in binary and multicomponent systems - Application to gas-liquid and liquid-liquid systems - Analogies in Mass Transfer, Reynolds, Chilton-Colburn-Prandtl, Von Karman Analogy.

UNIT 3: Distillation **9 Hours**

Vapour – liquid equilibria - Raoult's law and deviations from ideality – Methods of distillation – fractionation of binary and multicomponent system. Design calculations by McCabe-Thiele and Ponchon-Savarit Methods; continuous contact distillation tower (packed tower) design - Extractive and azeotropic - Distillation low pressure distillation - Steam distillation.

UNIT 4: Absorption **9 Hours**

Equilibrium and operating line concept in absorption calculations - Types of contactors – Design of packed and plate type absorbers - Operating characteristics of stage wise and differential contactors, concepts of NTU-HTU and overall volumetric mass transfer coefficients - Multicomponent absorption, mechanism and model of absorption with chemical reaction - Thermal effects in absorption process

UNIT 5: Humidification **9 Hours**

Basic concepts- psychrometric chart construction - Humidification and dehumidification operations, design calculations - Cooling tower principle and operation, types of equipment, design calculations

Total: 45 Hours

Textbook(s):

1. R. E. Treybal, Mass Transfer Operations, McGraw Hill, New York, 2017 (3rd Edition).

2. A. L. Hines and R. N. Maddox, Mass Transfer: Fundamentals and Applications, Prentice Hall, New York, 2016 (1st Edition).

Reference(s):

1. C. J. Geankopolis, Transport Processes and Separation Process Principles (Includes Unit Operations), Prentice Hall of India, New Delhi, 2018 (5th Edition).

2. R. Zarzytci, and A. Chacuk, Absorption: Fundamentals and Application, Pergamon Press, 2013 (1st Edition).

3. R. F. Strigle, Packed Tower Design and Applications, Gulf Publishing Company, USA, 1994 (2nd Edition).

4. P. C. Wankat, Equilibrium staged Separations, Prentice Hall, New York, 1988 (1st Edition)

212CHE2301	Mass Transfer II	L	T	P	C
		2	1	2	4
Prerequisite: Mass Transfer I	**Course Category:** Program Core **Course Type:** Theory				

Course Objective(s):

To understand the basic principles of Mass transfer in various unit operations and process.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Understand about the design procedure of adsorption column and to estimate the number of theoretical stages for different types of adsorption column

CO2: Able to understand and solve problems related to extraction, leaching and design of leaching equipments

CO3: Able to understand about the drying process design, drying equipments and solve problems related to drying

CO4: Understand about the crystallization process and the factors involved in crystallization

CO5: Know and explain about membrane separation operation

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H	H	H	H	M							
CO2		H		M	H				M			L
CO3		H		M	H					L		
CO4		H	H	H	M	H		L			L	
CO5		L	H	H	M		M					

UNIT 1: Adsorption **9 Hours**

Theories of adsorption of gases and liquids – Industrial adsorbents – Adsorption equipment for batch and continuous operation - Design calculation of ion-exchange resins, principle of ion-exchange, industrial equipment.

UNIT 2: Liquid-liquid extraction and Leaching **9 Hours**

Equilibrium in ternary systems - Equilibrium stage wise contact calculations for batch and continuous extractors – Differential contact extraction equipment- Spray-packed and mechanically agitated contactors and their design calculations - Pulsed extractors -

centrifugal extractors - Solid-liquid equilibria; leaching equipment - Batch and continuous types; calculation of number of stages.

UNIT 2: Drying **9 Hours**

Theory and mechanism of drying - Drying characteristics of materials - Batch and continuous drying – Calculation for continuous drying – Drying equipment - Design and performance of various drying equipments.

UNIT 4: Crystallization **9 Hours**

Nuclei formation and crystal growth - Theory of crystallization –Growth coefficients and the factors affecting these in crystallization - Batch and continuous industrial crystallizers - Principle of design of equipment

UNIT 5: Membrane Separation Processes **9 Hours**

Membrane separation process – Solid and liquid membranes – Concept of osmosis - Reverse osmosis – Electrodialysis – their applications – Foam separation process – Thermal and sweep diffusion process

Total: 45 Hours

List of Experiments

1. Diffusivity measurement
2. Wetted wall column
3. Vapor Liquid Equilibria
4. Simple Distillation
5. Steam Distillation
6. Packed Column Distillation
7. Bubble Cap Distillation
8. Hold Up studies in Spray Column, Plate Column and Packed Column
9. Extraction single stage and Multi stage crosscurrent
10. Leaching single stage and Multi stage crosscurrent
11. Batch adsorption and adsorption equilibria
12. Surface evaporation
13. Drying curve in a Tray drier

14. Crystallization

Textbook(s):

1. R. E. Treybal, Mass Transfer Operations, McGraw Hill New York, 2017 (3^{rd} Edition).

2. A. L. Hines and R. N. Maddox, Mass Transfer: Fundamentals and Applications, Prentice Hall, New York, 2016 (1^{st} Edition).

Reference(s):

1. C. J. Geankopolis, Transport Processes and Separation Process Principles (Includes Unit Operations), Prentice Hall of India, New Delhi, 2018 (5^{th} Edition).

2. R. F. Strigle, Packed Tower Design and Applications, Gulf Publishing Company, USA, 1994 (2^{nd} Edition).

3. P. C. Wankat, Equilibrium staged Separations - Prentice Hall - New York - 1988 (1^{st} Edition).

4., J. H. Harker, J. F. Richardson, J. M. Coulson, and R. P. Chhabra, Coulson and Richardson's Chemical Engineering Volume I, Butterworth-Heinemann,1999 (6^{th} Edition).

5. J. H. Harker, J. R. Backhurst, J. F. Richardson, and J. M. Coulson, Coulson and Richardson's Chemical Engineering Volume II, Butterworth-Heinemann, 2002 (5^{th} Edition)

6. Charles Holland - Fundamentals of Multicomponent Distillation, McGraw Hill, New York, 1997 (1^{st} Edition).

212CHE2302	Chemical Reaction Engineering	L	T	P	C
		2	1	2	4
Prerequisite: Nil	**Course Category:** Program Core **Course Type:** Integrated Course				

Course Objective(s):

To understand the conceptual design of reactors and its non-ideal behavior.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Describe the kinetics of reactions

CO2: Interpret reactor data and rate equation

CO3: Identify ideal reactors and explain the various aspects of design for single reactions

CO4: Explain the various aspects of design for multiple reactions

CO5: Analyse non-ideal behavior of reactors with suitable models

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H	M										
CO2	H		H	H								
CO3	H		H	M					L	L		
CO4	H		H	M					L	L		
CO5	H		H	M								

UNIT 1: Reaction Kinetics **9 Hours**

Chemical kinetics - Classification of reactions, variables affecting rate of reaction, definition of reaction rate - Kinetics of homogeneous reactions - Concentration dependent terms of rate equation - Elementary and non-elementary reactions, kinetic view of equilibrium for elementary reactions - Molecularity and order of reaction, representation of reaction rates - Testing kinetics models - Temperature dependency of rate - Rate of reaction predicted by theories

UNIT 2: Interpretation of Reactor Data and Rate Equation **9 Hours**

Interpretations of reactor data - Constant volume batch reactor - Integral methods of analysis - Autocatalytic reactions - First and second order reversible reactions - Differential method of analysis - Variable volume batch reactor - Temperature and reaction rate - Search for rate equation

UNIT 3: Ideal Reactors **9 Hours**

Ideal Reactors - Reactor design, batch reactor, semi batch reactor, single ideal reactors - Performance equations for batch, plug, mixed reactor - Design for simple reactions - Size comparison of single reactors, general graphical comparison - Multiple reactor systems - Mixed flow reactor of different type in series - Reactors of different types in series - Recycle reactor

UNIT 4: Multiple Reactions **9 Hours**

Design of reactor for multiple reactions - Reaction in series and parallel - Qualitative and quantitative treatment about product distribution - Successive irreversible reactions of different orders - kinetics of series-parallel reactions

UNIT 5: RTD Studies **9 Hours**

Basics of non-ideal flow- RTD in non-ideal flow; non-ideal flow models- Tank in series model and Axial Dispersion Model, conversion in non-ideal reactors

Total: 45 Hours

List of Experiments

1. Reversible reaction in a batch reactor

2. Irreversible reaction in a batch reactor (Equimolar mixture)

3. Irreversible reaction in a batch reactor (Non Equimolar mixture)

4. Arrhenius theory

5. Adiabatic batch reactor

6. RTD in mixed flow reactor

7. RTD in plug flow reactor

8. MFR in series

9. Combined reactors: PFR-MFR in series

10. Reactor modeling using DWSIM

11. Conversion Studies in Plug Flow Reactor using DWSIM

12. Conversion Studies in CSTR using DWSIM

Textbook(s):

1. O. Levenspiel, Chemical Reaction Engineering, Wiley Publications, New York, 2019 (3rd Edition).

2. G. F. Froment, K. B. Bischoff, Chemical Reactor Analysis and Design, Wiley Publications, New York, (3rd Edition).

3. H. S. Fogler, Elements of Chemical Reaction Engineering, Prentice Hall of India, New Delhi, 2016 (5^{th} edition).

Reference(s):

1. E. Davis Mark, J. J. Davis Robert, Fundamentals of Chemical Reaction Engineering, McGraw Hill, New York, 2003.

2. N. Bruce, Handbook of Chemical Reactor Design Optimization and Scale up - McGraw Hill, New York, 2002.

212CHE3301 Process Equipment Design And Drawing	L	T	P	X	C
	2	1	0	3	4

Prerequisite: Heat Transfer, Mass Transfer I & II	**Course Category:** Program Core **Course Type:** Integrated Course

Course Objective(s):

To understand the designing process and equipments of chemical Engineering and its applications in various aspects.

Course Outcome(s):

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

CO1: Design pressure vessels.

CO2: Design heat transfer equipments.

CO3: Design mass transfer equipments.

CO4: Design reactors.

CO5: Design jacketed vessels.

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1		M						M		L		
CO2	M			M			M					
CO3			M			M		L			M	
CO4				H					L			
CO5												M

UNIT 1: Pressure Vessels **12 Hours**

Design of High Pressure Systems - Design of high pressure vessels (internal and external pressures), Vessel accessories - Nozzles, flanges, openings and reinforcements and supports of vessels.

UNIT 2: Heat Exchangers **12 Hours**

Process Design of Heat Exchangers - DPHE and types of heat exchanger - Shell and tube heat exchanger.

UNIT 3: Heat Transfer Equipments **12 Hours**

Process design of evaporator, types of evaporator, methods of feeding evaporators. Design of evaporator, Crystallizer design, types of crystallizer. Design of Crystallizer.

UNIT4: Mass Transfer Equipments I **12 Hours**

Design of mass transfer equipments - Distillation and absorption (plate and packed) columns, Cooling Towers.

UNIT 5: Mass Transfer Equipments II **12 Hours**

Extraction columns - Process design of dryer, Design of rotary dryer and tray dryer.

Total: 60 Hours

Text Book(s):

1.S. M. Walas, Process Equipment Selection and Design, Elsevier Science, 2012 (3rd Edition).

2. J. M. Coulson, J. F. Richardson, J. R. Backhurst, J. M. Harker, and K. Sinnott, Coulson and Richardson’s Chemical Engineering Series Volume 6, Butterworth-Heinemann, Oxford, 2002 (5th Edition).

Reference(s):

1. Don W. Green, Robert H. Perry, Perry's Chemical Engineers' Handbook, McGraw Hill, New York, 2008 (8th Edition).

2. Max S. Peters, Klaus D. Timmerhaus, and Ronald. E. West, Plant Design and Economics for Chemical Engineers, McGraw Hill, New York, 2002 (5th Edition).

3. Warren M. Rohsenow, James P. Hartnett, Young I. Chou, Handbook of Heat Transfer, McGraw Hill, New York, 1998 (3rd Edition).

4. J. M. Douglas, Conceptual Design of Chemical Processes, McGraw Hill, New York, 1988.

212CHE3302	Process Dynamics and Control	L	T	P	C
		2	1	2	4

Prerequisite: Partial Differential Equations and Transforms

Course Category: Program Core

Course Type: Integrated Course

Course Objective(s):

To understand the simulation process for a frequency system and come to know about the software related processes.

Course Outcome(s):

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

CO1: Analyze open-loop systems.

CO2: Analyze and apply the knowledge of linear closed loop systems.

CO3: Analyze the transient response of closed loop systems.

CO4: Develop working knowledge of control system by frequency response.

CO5: Analyze Frequency response and apply it to advanced control systems.

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1		M										
CO2	M	L		M								
CO3		L	M									
CO4		L		H								
CO5		L					M					

UNIT 1: Open Loop Systems **9 Hours**

Laplace Transforms - Standard functions, Open loop systems, First order systems and their transient response for standard input functions, First order systems in series, Linearization and its application in process control, Second order systems and their dynamics.

UNIT 2: Closed Loop Systems **9 Hours**

Closed loop control systems, development of block diagram for feed-back control systems, servo and regulatory problems, transfer function for controllers and final control element, principles of pneumatic and electronic controllers, transportation lag, dead time.

UNIT 3: Transient Response **9 Hours**

Transient response of closed-loop control systems, Routh-Hurwitz and Root-locust ability of a control System.

UNIT 4: Frequency Response **9 Hours**

Introduction to frequency response of closed-loop systems, Control system design by frequency response techniques, Bode diagram, Principle of Nyquist diagram, Stability criterion, Tuning of controller settings.

UNIT 5: Advanced Control Systems 9 Hours

Introduction to advanced control systems, cascade control, feed forward control, model predictive control, Control of distillation Column and heat exchanger. Adaptive controller, Supervisory controller and Ratio Controller - Introduction to computer control systems.

Total: 45 Hours

Text Book(s):

1. D. R. Coughnowr, and S. E. LeBlanc, Process Systems Analysis and Control, McGraw Hill, New York, 1991 (3rd Edition).

2. George Stephanopoulos, Chemical Process Control, Prentice Hall of India Pvt. Ltd., New Delhi, 1990 (3rd Edition).

3. Dale E. Seborg, Duncan A. Mellichamp, Thomas F. Edgar, Francis J. Doyle, Process Dynamics & Control, Prentice Hall of India Pvt. Ltd., New Delhi.

Reference(s):

1. Ernest O. Doeblin and Dhanesh N. Manik, Measurement Systems, McGraw Hill, New York, 2017 (6th edition).

2. Carlos A. Smith, and Armando B. Corripio, Principles and Practice of Automatic Process Control, Wiley Publications, 2005 (3rd Edition).

3. Michael L. Luyben, and William L. Luyben, Essentials of Process Control, McGraw Hill, New York, 1997.

4. Donald P. Eckman, Industrial Instrumentation, Wiley Publications, Singapore, 1990.

5. Peter Harriot, Process Control, Tata McGraw Hill, New Delhi, 1991.

212CHE3303	Process Modeling and Simulation	L	T	P	C
		2	1	0	3

Prerequisite: Nil

Course Category: Program Core

Course Type: Integrated Course

Course Objective(s):

To understand the modeling & simulation techniques of chemical processes and to gain skills in using process model simulators and to apply the numerical methods to solve chemical engineering problems.

Course Outcome(s):

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

CO1: Understand the concept of modeling & simulation, analyze the steady state degree of freedom and Apply and solve unsteady state equations

CO2: Demonstrate understanding of common numerical methods and how they are used to obtain approximate solutions to otherwise intractable mathematical problems.

CO3: Apply numerical methods to obtain approximate solutions to mathematical problems. And derive numerical methods for various mathematical operations and tasks, such as interpolation, differentiation, integration, the solution of linear, nonlinear and differential equations.

CO4: Analyze and evaluate the accuracy of common numerical methods.

CO5: Develop Finite difference solution for one dimensional heat equation.

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H	M			M							
CO2	H	L	M	M	M			H	M		L	
CO3	H	L	M								L	
CO4	H	L								H	M	
CO5	M	L	M	H	H		M					H

UNIT 1: Introduction and Steady State Lumped Systems 12 Hours

Introduction to modeling and simulation, classification of mathematical models, conservation equations and auxiliary relations. Degree of freedom analysis, single and network of process units, systems yielding linear and non-linear algebraic equations, flow sheeting – sequential modular and equation oriented approach, tearing, partitioning and precedence ordering, solution of linear and non-linear algebraic equations

UNIT 2: Unsteady State Lumped Systems & Steady State Distributed Systems 12 Hours

Characteristics for through pipe analysis of liquid level tank, gravity flow tank, jacketed stirred tank heater, reactors, flash and distillation column, solution of ordinary differential equations initial value problems, matrix differential equations, Simulation of closed loop systems. Analysis of compressible flow, heat exchanger, packed columns, plug flow reactor, solution of ODE boundary value problems.

UNIT 3: Solution of Equations and Eigen Value Problems **12 Hours**

Review of open end methods, bracketed end methods - The intermediate theorem (excluding proof) - Iterative method, False position method, Newton-Raphson method for single variable and for simultaneous equations with two variables - Solutions of a linear system by Gaussian, Gauss-Jordan, Jacobi and Gauss - Seidel methods - Eigen value of a matrix by Power Method.

UNIT 4: Interpolation, Numerical Differentiation, Integration and Finite Element Methods **12 Hours**

Newton forward and backward difference formulae - Newton's divided difference formulae - Lagrange's polynomials - Numerical differentiation with interpolation polynomials - Numerical integration by Trapezoidal and Simpson's (both $1/3^{rd}$ and $3/8^{th}$) rules. Line segment element - triangular element - rectangular element - quadrilateral element - tetrahedron element - hexahedron element - curved boundary element - Numerical integration over finite elements - Ritz finite element method - Least square finite element method - Galerkin finite element method - convergence analysis.

UNIT 5: Initial Value and Boundary Value Problems for PDE **12 Hours**

Single step Methods - Taylor Series, Euler and Modified Euler, Runge - Kutta method of order four for first and second order differential equations - Multistep Method - Milne predictor and corrector method, Finite difference solution for the second order ordinary differential equations - Finite difference solution for one dimensional heat equation (both implicit and explicit)

Total: 60 Hours

Text Book(s):

1. W. Fred Ramirez, Computational Methods in Process Simulation, Butterworth-Heinemann, Oxford, 1997 (2^{nd} Edition).

2. Amiya K. Jana, Chemical Process Modelling and Computer Simulation, Prentice Hall India Learning Pvt. Ltd., 2011 (2^{nd} Edition).

3. S. K. Gupta, Numerical Methods for Engineers, New Academic Science Publications, 2014.

Reference(s):

1. Steven C. Chapra, and Raymond P. Canale, Numerical Methods for Engineers with Personal Computer Applications, McGraw Hill, New York, 2012 (2^{nd} Revised Edition).

2. Richard L. Burden, J. Douglas Faires, and Annette M. Burden, Numerical Analysis, Cengage Learning, 2010 (9th Edition).

3. Kendall E. Atkinson, An Introduction to Numerical Analysis, Wiley Publications, 1989 (2nd Edition).

4. William H. Press, Saul A. Teukolsky, William T. Vetterling, and Brian P. Flannery, Numerical Recipes in C: The Art of Scientific Computing, Cambridge University Press, 2007(3rd Edition).

5. William L. Luyben, Process Modelling Simulation and Control, McGraw Hill, New York, 1989 (2nd Edition).

6. Richard M. Felder, Ronald W. Rousseau, and Lisa G. Bullard, Elementary Principles of Chemical Processes, Wiley Publications, 2018 (4th Edition).

7. Srikumar Koyikal, Chemical Process Technology and Simulation, Prentice Hall India Learning Pvt. Ltd., 2013.

212CHE3101	Transport Phenomena	L	T	P	C
		2	1	0	3
Prerequisite: Fluid Mechanics	**Course Category:** Program Core **Course Type:** Theory				

Course Objective(s):

To understand the properties of transport processes and to apply heat and momentum transfer analysis.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Explain the properties of transport processes

CO2: Analyze industrial problems along with appropriate boundary conditions.

CO3: Develop steady and time dependent solutions along with their limitations.

CO4: Understand unsteady state flows and the flow through circular pipes.

CO5: Apply heat and mass transfer analysis.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1					M							
CO2	H	M			H							
CO3					H							
CO4				H	M	M	M				M	M
CO5				H		M					M	

UNIT 1: Transport properties and Reynolds transport theorem 9 Hours

Laminar Flow - Transport properties and mechanism - Rate process - flux - types of fluids – phenomenological laws - Rheology of non- Newtonian fluids - Flow through circular pipes - Mathematical foundation, types of time derivatives, divergence operators, control volume - Overall mass, energy and momentum balances - Extended Bernoulli’s equation - Reynolds’s transport equation.

UNIT 2: Equations of Motion and Flow Properties 9 Hours

Equation of motion - Equation of change based on differential balance - Equation of continuity – Navier-Stokes equation, energy equation, application of Navier-Stokes equation to various flows through different geometric shapes, applications of energy equation - Potential, streamline, creeping and ideal flow.

UNIT 3: Boundary Layer Theory **9 Hours**

Boundary Layer Theory – Flow around submerged solids, flow past flat plate – Boundary layer-Prandtl equation - Expressions for viscous drag - Thermal boundary layer - Von Karman's integral momentum equation, analysis of integral equation, displacement thickness.

UNIT 4: Turbulent Flow **9 Hours**

Turbulent Flow - Turbulent flow mechanism – Intensity of turbulence - Reynolds's stress – Prandtl mixing length - Turbulent flow through circular pipes.

UNIT 5: Heat and Mass Transfer Analysis **9 Hours**

Heat Transfer Analysis: Analogies of transfer processes, profiles of gradients, Reynolds's-Prandtl, Von-Karman, Chilton-Colburn analogies, j factors, Dittus- Boelter's equation. Mass Transfer Analysis: Mass transfer in binary systems without chemical reactions, Mass balance with chemical reaction, Theories of interphase mass transfer, Mass transfer analogies.

Total: 45 Hours

Textbook(s):

1. R. B. Bird, W. E. Stewart, and E. N. Lightfoot, Transport Phenomena, Wiley Publications, 2007 (Revised 2nd Edition).

2. R. S. Brodkey, and H. C. Hershey, Transport Phenomena: A Unified Approach, Volume 1 & 2, McGraw Hill, New York, 2003 (2nd Edition).

Reference(s):

1. C. J. Geankopolis, Transport Processes and Separation Process Principles (Includes Unit Operations), Prentice Hall of India Pvt. Ltd., New Delhi, 2003 (4th Edition).

2. W. M. Deen, Analysis of Transport Phenomena, Oxford University Press, 2013 (2nd Edition).

3. J. R. Welty, C. E. Wicks, G. L. Rorrer. and R. E. Wilson, Fundamentals of momentum, heat, and mass transfer, Wiley Publications, 2010 (5th Edition).

212CHE1104	Partial Differential Equations and Transforms	L	T	P	C
		2	1	0	3
Prerequisite: Fluid Mechanics	**Course Category:** Program Core **Course Type:** Theory				

Course Objective(s):

To enable the students to solve the partial differential equations, to understand discrete and continuous transformations, and to solve differential equations and difference equations using transform techniques.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Know the method of solving first and second order partial differential equations.

CO2: Classify the second order partial differential equations and to know about solving of initial and boundary value problems.

CO3: Understand the concept of Laplace transform and its application in solving ordinary differential equations and partial differential equations.

CO4: Know about Z transform and its application in solving difference equations.

CO5: Know about Fourier transforms and its properties.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H	H										
CO2	H	H										
CO3	H	H		M								
CO4	H	H		M								
CO5	H	H					L					

UNIT 1: Partial Differential Equations **9 Hours**

First order partial differential equations, solutions of first order linear and non-linear PDEs. Solution to homogenous and non-homogenous linear partial differential equations second and higher order by complimentary function and particular integral method.

UNIT 2: Applications of Partial Differential Equations **9 Hours**

Flows, vibrations and diffusions, second-order linear equations and their classification, Initial and boundary conditions, solution of the wave equation and diffusion equation by the method of separation of variables, The Laplacian in plane, cylindrical and spherical polar coordinates and solutions.

UNIT 3: Laplace Transform **9 Hours**

Laplace Transform, Properties of Laplace Transform, Laplace transform of periodic functions. Finding inverse Laplace transform by different methods, convolution theorem. Evaluation of Integrals by Laplace transform, solving ODEs and PDEs by Laplace Transform method.

UNIT 4: Z Transform **9 Hours**

Z-transform - Elementary properties - Inverse Z - transform - Convolution theorem – Formation of difference equations - Solution of difference equations using Z - transform.

UNIT 5: Fourier Transform **9 Hours**

Fourier series – Half range sine and cosine series - Fourier integral theorem (without proof) - Fourier Transform pair - Sine and Cosine transforms – Properties - Transforms of simple functions – Convolution theorem - Parseval's Identity.

Total: 45 Hours

Textbook(s):

1. T. Veerarajan, Engineering Mathematics (for semester III), Tata McGraw-Hill, New Delhi, 2010.

2. T. Veerarajan, Engineering Mathematics (For First Year), Tata McGraw-Hill publishing company Limited, 2008.

Reference(s):

1. E. Kreyszig, Advanced Engineering Mathematics, John Wiley and Sons (Asia) Limited, Singapore, 2001 (10^{th} Edition).

2. B. S, Grewal, Higher Engineering Mathematics, Khanna Publishers, New Delhi, 2004 (37^{th} Edition).

211MEC1106 ENGINEERING MECHANICS	L	T	P	X	C
	2	1	0	0	3
Pre-requisite: Nil	Course Category: Program core course Course type: Theory and Practical				

Course Objective(s):

To enable the students to solve the partial differential equations, to understand discrete and continuous transformations, and to solve differential equations and difference equations using transform techniques.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Know the method of solving first and second order partial differential equations.

CO2: Classify the second order partial differential equations and to know about solving of initial and boundary value problems.

CO3: Understand the concept of Laplace transform and its application in solving ordinary differential equations and partial differential equations.

CO4: Know about Z transform and its application in solving difference equations.

CO5: Know about Fourier transforms and its properties.

Mapping of course outcomes:

CO/PO	**PO**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
CO1	H	H										
CO2	H	H										
CO3	H	H		M								
CO4	H	H		M								
CO5	H	H					L					

Unit-I: STATICS OF PARTICLES AND RIGID BODIES

Six Fundamental principles and concepts - Force - System of Forces - Coplanar Concurrent Forces - Components in Space, Resultant of forces acting on the particle - Particle in equilibrium – concepts in 2 -D & 3-D – Equations of Equilibrium of Coplanar Systems and Spatial Systems. Rigid Body - Moment of Forces and its Application - Couples and Resultant of Force System equilibrium in 2-D – Supports and its reactions - Pin support - roller support.

Unit-II: ANALYSIS OF TRUSSES AND BEAMS

Basic Structural Analysis- Equilibrium in three dimensions - Method of Sections- Method of Joints- How to determine if a member is in tension or compression- Simple Trusses- Zero force members- Beams & types of beams – Shear force diagram – Bending Moment diagram.

Unit-III: FRICTION

Types of friction, limiting friction, Laws of Friction, Static and Dynamic Friction - Motion of Bodies, simple contact friction, sliding block, wedge friction, rolling resistance – Rope and Belt friction.

Unit-IV: PROPERTIES OF SURFACES AND SOLIDS

Centroid of simple figures from first principle, centroid of composite sections - Centre of Gravity and its implications - Area moment of inertia - Definition, Moment of inertia of plane sections from first principles, Theorems of moment of inertia, Moment of inertia of standard sections (T section and I section) - Mass moment inertia of circular plate, Cylinder, Cone, Sphere- Principal moment of inertia.

Unit-V: DYNAMICS

Review of particle dynamics - Displacements, velocity and acceleration, their relationship - Equations of motions - Rectilinear motion- Plane curvilinear motion - Newton's 2nd law- Impulse, momentum, impact - D'Alembert's principle and its applications in plane motion and connected bodies - Work energy principle and its application in plane motion of connected bodies - Virtual Work and Energy Method - Virtual displacements, principle of virtual work for particle and ideal system of rigid bodies.

Text Book:

1. Ferdinand P. Beer, E. Russell Johnston, David Mazurek, Phillip J. Cornwell, Brian Self, Sanjeev Sanghi, "*Vector Mechanics for Engineers – Statics and Dynamics*", Edition: 12, McGraw Hill, 2019.
2. J. L. Merriam, "*Engineering Mechanics*", Edition: 7, Wiley, 2017.

Reference(s):

1. R. K. Jain, "*Production Technology*", Edition: 19, Khanna Publisher, 2019.
2. P. Mikell Groover, "*Fundamentals of Modern Manufacturing: Materials, Processes, and Systems*", Edition: 7, Wiley, 2018.

Program Electives

213CHE2101	Heterogeneous Catalysis	L	T	P	C
		3	0	0	3
Prerequisite: Fluid Mechanics	**Course Category:** Program Elective **Course Type:** Theory				

Course Objective(s):

To learn, discuss and apply knowledge of the chemical structure and reactivity of industrial catalytic compounds, with particular emphasis placed upon the integration of fundamental catalytic chemistry with the principles of chemical reaction engineering, transport phenomena and thermodynamics.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Explain the fundamentals of reaction mechanism & kinetics

CO2: Apply the perception of non-catalytic fluid-solid reactions

CO3: Analyze the mechanism of non-catalytic gas-liquid reactions

CO4: Design reactors for solid catalyzed reactions

CO5: Apply the kinetics of multiphase reactions.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H	M		M								
CO2		H		H								
CO3			H	H				M				
CO4			H	H				M				
CO5					M							

UNIT 1: Transport Processes in Heterogeneous Catalysis 9 Hours

Transport processes in heterogeneous catalysis - Interfacial gradient effects, reaction at a catalyst surface, concentration and temperature differences across the external - Film of a catalyst pellet, mass transfer on metallic surfaces – Intra particle gradient effects - Catalyst internal structure – Pore diffusion, reaction and diffusion within a catalyst pellet - Effectiveness factor and generalized effectiveness factor, Temperature gradients within a catalyst pellet - Weisz-Prater criteria, combined interfacial and intra particle resistances.

UNIT 2: Non-Catalytic Fluid-Solid Reactions **9 Hours**

Non-catalytic fluid-solid reactions - Total particle dissolution - Shrinking core model, reactor Design - Fluidized bed reactors, fluidization principles, key applications - Two and three phase models, Transport reactor design - Catalyst deactivation functions.

UNIT 3: Non-Catalytic Gas-Liquid Reactions **9 Hours**

Absorption combined with chemical reactions - Mass transfer coefficients and kinetic constants - Application of two film and surface renewal theories - Hatta number - Enhancement number for first order reactions.

UNIT 4: Fixed Bed Catalytic Reactor Design **9 Hours**

Pseudo-homogeneous PFR and axially dispersed PFR models - Heterogeneous models - Use of effectiveness factor - Use of intra particle diffusion equations - Two dimensional models.

UNIT 5: Multiphase Reactors **9 Hours**

Two-film theory, Hatta number - General design m52odels, simplifications to design models, instantaneous, fast and slow reactions, solid catalyzed reactions, resistances in series chemical engineering and chemical technology approximation - Selection of gas-liquid contactors.

Total: 45 Hours

Textbook(s):

1. James J. Carberry, Chemical and Catalytic Reaction Engineering, Dover Publications, 2001 (Reprint 1st Edition).

2. John Meurig Thomas, and W. John Thomas, Principles and Practice of Heterogeneous Catalysis, Wiley Publications, 2014 (Revised 2nd Edition).

Reference(s):

1. H. Scot Fogler, Elements of Chemical Reaction Engineering, Prentice Hall India Learning Pvt. Ltd., 2008 (4th Edition).

2. Gilbert F. Froment, Kenneth B. Bischoff, and Juray De Wilde, Chemical Reactor Analysis and Design, Wiley Publications, 2010 (3rd Edition).

213CHE1101	Polymer Science And Technology	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** Program Elective **Course Type:** Theory				

Course Objective(s):

To introduce basic concepts regarding drug engineering which serves as the backbone of medical and pharmaceutical industry.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Ability to identify the common commercial polymers by their names, properties and syntheses

CO2: Understand the properties and applications of polymers processing methodology

CO3: Apply the mechanisms of polymer degradation

CO4: Analyze the polymer additives and their role in the control of desired properties

CO5: Perform various polymer fabrication methods of extrusion, moulding and conversion of fibres to fabrics.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	M											
CO2			H									
CO3		M										
CO4			H									
CO5						M						

UNIT 1: Introduction **9 Hours**

Classification and characterization of polymers - Thermal analysis, Morphological characterization, Physical testing.

UNIT 2: Properties of Polymer **9 Hours**

Morphology and order in crystalline polymers - Rheology and mechanical properties of polymer structure and physical properties.

UNIT 3: Polymerization **9 Hours**

Polymerization - Step reaction polymerization, Chain reaction polymerization, free radical, anionic, cationic, coordination - Copolymers and Copolymerization - Polymerization conditions.

UNIT 4: Plastics and Resins **9 Hours**

Hydrocarbon plastics and elastomers - Other carbon chain polymers – Hetero chain thermoplastics - Thermosetting Resins - Types of deformation.

UNIT 5: Technologies **9 Hours**

Plastic technology - Fiber technology- Elastomer technology.

Total: 45 Hours

Textbook(s):

1. F. W. Billmeyer, Text book of Polymer Science, Wiley Publishers, Singapore, 1994 (3rd Edition).

2. A. Rudin, Elements of Polymer Science and Engineering an Introductory Text and Reference for Engineers, Elsevier, New Delhi, 1998 (2nd Edition).

Reference(s):

1. Anil Kumar, and R. K. Gupta, Fundamentals of Polymers, McGraw Hill, New York, 1998.

2. N. P. Cheremisinoff, Polymer Mixing and Extrusion Technology, CRC Press, 2017.

3. F. Rodriguez, Principles of polymer systems, Taylor and Francis, Washington, 1996.

213CHE1102	Interfacial Science and Engineering	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** Program Elective **Course Type:** Theory				

Course Objective(s):

To understand the colloid, colloidal state, preparation of colloids, concepts in interfacial science, experimental techniques used to determine colloidal properties and interfacial phenomena.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Describe the colloidal state, including colloids and their preparation and properties.

CO2: Ability to discuss the fundamental concepts in colloid and interface science.

CO3: Understand the impact factors that will affect the colloidal systems.

CO4: Discuss important factors on solid/liquid interactions.

CO5: Explain experimental techniques and used to determine colloidal properties and interfacial phenomena.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1			M							L		
CO2				L								
CO3		M	H			L						
CO4	H						M				L	
CO5							H					

UNIT 1: Basic Concepts of Colloids and Interfaces 9 Hours

Introduction - Examples of Interfacial Phenomena - Solid-Fluid Interfaces - Colloids. Properties of Colloid Dispersion - Sedimentation under gravity - Sedimentation in a centrifugal field - Brownian motion - Osmotic pressure - Optical properties - Electrical properties - Rheological properties of colloid dispersions.

UNIT 2: Surfactants and Their Properties **9 Hours**

Introduction - Surfactants and their properties - Emulsions and Micro emulsion - foams. Surface and Interfacial Tension - Contact angle and Wetting - Shape of the Surfaces and interfaces.

UNIT 3: Surface and Interfacial Tension **9 Hours**

Measurement of Surface and Interfacial Tension - Measurement of Contact Angle - Intermolecular and Surface forces - Vander walls forces - Electrostatic double layer force, DLVO theory – Non DLVO forces.

UNIT 4: Adsorption at Interfaces **9 Hours**

Introduction - The Gibbs Dividing surface - Gibbs Adsorption Equation - Langmuir and Frumkin Adsorption isotherms, Surface equation of state (EOS) - Effect of Salt on adsorption of surfactants.

UNIT 5: Adsorption Isotherms **9 Hours**

Adsorption isotherms incorporating the electrostatic effects - Calculation of free energy of adsorption - Adsorption of inorganic salts at interfaces - Dynamics of adsorption of Surfactants at the interfaces - Adsorption at solid - Fluid interfaces.

Total: 45 Hours

Textbook(s):

1. Pallab Ghosh, Colloid and Interface Science - Prentice Hall India Learning Pvt. Ltd., New Delhi, 2009.

2. Robert J. Hunter, Foundations of Colloid Science, Oxford University Press, Oxford, 2010 (2^{nd} Edition).

Reference(s):

1. Paul C. Hiemenz and Raj Rajagopalan, Principles of Colloid and Surface Chemistry (Revised and Expanded), CRC Press, Taylor and Francis Group, 2016 (3^{rd} Edition).

2. Arthur W. Adamson, Alice P. Gast, Physical Chemistry of Sciences, Wiley Publications, 2013 (6^{th} Edition).

3. G. Barnes, and I. Gentle, Interfacial Science: An Introduction, Oxford University Press, Oxford, 2011 (2^{nd} Edition).

213CHE2102	Process Utilities And Pipeline Design	L	T	P	C
		3	0	0	3

Prerequisite: Process Equipment Design and Drawing

Course Category: Program Elective

Course Type: Theory

Course Objective(s):

To impart the basic concepts of project engineering and to develop understanding about process auxiliaries and utilities in process industries.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Learn about the overall knowledge about the process plant.

CO2: Understand the importance of process auxiliaries

CO3: Understand the significance of utilities in process industries.

CO4: Learn the conceptual design of chemical process equipment.

CO5: Build a bridge between theoretical and practical concepts used for process auxiliaries and utilities in any process industry.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H	L										
CO2		H			M							
CO3					M		L					
CO4	H			H								
CO5	M		H		M							

UNIT 1: Process Water **9 Hours**

Process Water: Sources of water, hard and soft water, Requisites of industrial water and its uses, Methods of water treatment, Chemical softening, Demineralization, Resins used for water softening, Water for boiler use, cooling purposes, cooling towers, Drinking and process water treatment, Reuse and conservation of water, Water resources management, Waste water treatment and disposal.

UNIT 2: Steam **9 Hours**

Steam: Steam generation and its application in chemical process plants, Distribution and utilization, Boilers, Design of efficient steam heating systems, Steam economy, Condensate utilization, Steam traps and their characteristics, Selection and application, Waste heat Utilization.

UNIT 3: Pipeline Design **9 Hours**

Piping design: Selection of material, Pipe sizes, working pressure, Basic principles of piping design, piping drawings, Pipe installations, Overhead installations, Process steam piping, Selection and determination of steam, Pipe size, Piping insulation, Application of piping insulation, Weather proof and fire resisting pipe insulation jackets, Pipe fittings and joints.

UNIT 4: Compressors and Vacuum Pumps **9 Hours**

Compressors and Vacuum Pumps: Types of compressors and vacuum pumps and their performance characteristics, Methods of vacuum development and their limitations, Materials handling under vacuum, Lubrication and oil removal in compressors and pumps, Instrument air.

UNIT 5: Process Control **9 Hours**

Process control and instrumentation diagram, Control system design for process auxiliaries, Refrigeration and chilling systems, Oil heating systems, Nitrogen systems, Valves, Types of valves, Selection criteria of valves for various systems.

Total: 45 Hours

Textbook(s):

1. Max S. Peters, Klaus D. Timmerhaus, and Ronald. E. West, Plant Design and Economics for Chemical Engineers, McGraw Hill, New York, 2002 (5th Edition).

2. F. C. Vibrandt and C. E. Dryden - Chemical Engineering Plant Design - McGraw Hill, New York, 1959 (4th Edition).

Reference(s):

1. Roger Hunt and Ed Bausbacher, Process Plant layout and Piping Design, Pearson Prentice Hall Inc., 1993 (1st Edition).

2. Jack Broughton; Process Utility Systems: Introduction to Design, Operation, and Maintenance; Institution of Chemical Engineers, U.K., 1994 (1st Edition).

213CHE2103	Boundary Layer Theory	L	T	P	C
		3	0	0	3
Prerequisite: Fluid Mechanics	**Course Category:** Program Elective **Course Type:** Theory				

Course Objective(s):

To understand the boundary layer flows, governing equations of fluid flow for different flow regimes, different geometries under the effect of various boundary conditions. Also to get familiar with turbulent flows and its models.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Apply the basic laws of fluid flow.

CO2: Analyze boundary layer equations.

CO3: Differentiate laminar and turbulent flows.

CO4: Apply momentum integral equation.

CO5: Explain heat transfer in boundary layers.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H			L								
CO2		H										
CO3			H									
CO4			M								M	
CO5		L		H								M

UNIT 1: Basic Laws of Fluid Flow **9 Hours**

Basic laws of fluid flow - Continuity, momentum and energy equations applied to system and control volume - Concepts of flow fields - Flow around bodies - Moment of momentum theorem and its application to fixed and moving vanes - Hot wire and Laser Doppler anemometry.

UNIT 2: Development of Boundary Layer **9 Hours**

Development of boundary layer- Estimation of boundary layer thickness, Displacement thickness, Momentum and energy thicknesses for two dimensional flow- Discussion of Navier Stokes equations - Two dimensional boundary layer equations – Blasius solution.

UNIT 3: Laminar and Turbulent Flow **9 Hours**

Laminar and turbulent flows on a flat plate - Laminar and turbulent boundary layers - Transition from laminar to turbulent boundary layers.

UNIT 4: Momentum Integral Equation **9 Hours**

Momentum Integral Equation for boundary layer flow - Introduction to symmetric and three dimensional boundary layer equations - Von Karman –Pol Hausen method.

UNIT 5: Introduction to Heat Transfer in Boundary Layers **9 Hours**

Introduction to heat transfer in boundary layers - Thermal boundary layer - Turbulent boundary layer on a flat plate - Flows in pressure gradient – Boundary layer control.

Total: 45 Hours

Textbook(s):

1. Ronald L. Panton, Incompressible Flow, Wiley Publications, Singapore, 2013 (4th Edition).

2. John D. Anderson, Fundamentals of Aerodynamics McGraw Hill, New York, 2016 (6th Edition).

Reference(s):

1. Tuncer Cebeci, and Peter Bradshaw, Momentum transfer in boundary layers, Hemisphere Publishing Corporation, Washington, 1977.

2. Herrmann Schlichting, and Klaus Gersten, Boundary Layer Theory, Springer Berlin Heidelberg, 2018, (9th Edition).

213CHE1103	Nanoscience And Technology	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** Program Elective **Course Type:** Theory				

Course Objective(s):

To understand the nanomaterials, nanodevices and nanostructure characteristics, to identify the electron microscopic techniques, the mechanism of mesoscopic magnetism, application of nanotechnology in nanoelectronics, bimolecular motors and drug delivery nano device.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Explain the characteristics of nanomaterials, nano devices and nanostructures.

CO2: Identify various Electron microscopic techniques.

CO3: Describe the mechanism of Mesoscopic magnetism.

CO4: Elucidate the applications of nanotechnology in nanoelectronics.

CO5: Suggest a suitable Bio molecular motors & drug delivery nanodevice.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1					M			M				
CO2					M	H			L			
CO3		L			M	H						
CO4		M	M	M	H						M	
CO5	L	M		M	H			M				

UNIT 1: Nanomaterials - Introduction **9 Hours**

Nanomaterials - Types, nanowires, nanotubes, fullerenes, quantum dots, dendrimers, Nanocomposites - Properties - Methods of preparation -Top down, bottom up.

UNIT 2: Electron Microscopic Techniques **9 Hours**

Electron Microscopy Techniques - SEM, TEM, X-ray methods - Optical Methods - Fluorescence Microscopy - Single molecule Surface Enhanced Resonance Raman Spectroscopy - Atomic Force Microscopy, MRI, STM and SPM.

UNIT 3: Mesoscopic Magnetism **9 Hours**

Mesoscopic magnetism - Magnetic measurements miniature hall detectors, Integrated DC SQUID Microsusceptometry - Magnetic recording technology - Biological Magnets.

UNIT 4: Basics of Nanoelectronics **9 Hours**

Basics of nanoelectronics - Single Electron Transistor, Quantum Computation – Parallel architecture for nano systems - Nanolithography, basic structures and integrated structures – MEMS and NEMS - Dynamics of NEMS - Limits of integrated electronics.

UNIT 5: Bio Molecular Motors **9 Hours**

Biological structures and functions – Bio molecular motors, drug delivery systems - Nano fluidics.

Total: 45 Hours

Textbook(s):

1. Jonathan W. Steed, and Jerry L. Atwood, Supramolecular Chemistry, Wiley Publications, 2009 (2nd Edition).

2. Jacob N. Israelachvili, Intermolecular and Surface Forces with applications to Colloidal and Biological systems (Colloid Science), Academic Press, London, 2011, (3rd Editions).

3. Katsuhiko Ariga, and Toyoki Kunitake, Supramolecular Chemistry, Fundamentals and Applications Advanced Textbook, Springer Berlin Heidelberg, 2006 (1st Edition).

Reference(s):

1. John. S. Rowlinson, A Scientific History of Intermolecular Forces, Cambridge University Press, 2002.

2. Jean-Marie Lehn, Supramolecular Chemistry Concepts and Perspectives, Wiley Publications, 2002.

213CHE1104	Green Technology	L	T	P	C
		3	0	0	3

Prerequisite: Nil

Course Category: Program Elective

Course Type: Theory

Course Objective(s):

This course gives an exposure to Green Technology concepts and evolution. It will be platform to understand the concepts of CSR and CER. The students learn the environmental acts and its applications.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: The Student can learn Green Technology concepts and relevance in 21st century requirements.

CO2: The knowledge of how to go Green in organization and sustainability issues.

CO3: Ability to know the ecosystem balance.

CO4: Ability to know about ISO 14001 and ISO 14064.

CO5: Understand about finance aspects of green technology.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1		H			H							
CO2							L					
CO3	L		M					H				
CO4					H							
CO5		H										

UNIT 1: Introduction **9 Hours**

The concept of green Technology; evolution; nature, scope, importance and types; developing a theory; green technology in India; relevance in twenty first century.

UNIT 2: Sustainability & Environment **9 Hours**

Organizational environment; internal and external environment; Indian corporate structure and environment; how to go green; spreading the concept in organization; Environmental and sustainability issues for the production of high-tech components and materials, life cycle analysis of materials, sustainable production and its role in corporate social responsibility (CSR) and corporate environmental responsibility(CER).

UNIT 3: Ecosystem Approaches **9 Hours**

Approaches from ecological economics; indicators of sustainability; ecosystem services and their sustainable use; bio-diversity; Indian perspective; alternate theories.

UNIT 4: Acts of Green Technology **9 Hours**

Environmental reporting and ISO 14001; climate change business and ISO 14064; green financing; financial initiative by UNEP; green energy Technology; green product Technology.

UNIT 5: Green Economics **9 Hours**

Definition; green techniques and methods; green tax incentives and rebates (to green projects and companies); green project Technology in action; business redesign; eco-commerce models.

Total: 45 Hours

Textbook(s):

1. Jazmin Seijas Nogarida, Green Technology and Green Technologies: Exploring the Causal Relationship, CCRS Working Paper Series, 2008 (3^{rd} edition).

2. John F. Wasik, Green Marketing and Technology: A global Perspective, Wiley–Blackwell, 2005 (3^{rd} edition).

Reference(s):

1. Leo A. Meyer, The Green Energy Management Book, LAMA Books, 2009.

2. Richard Maltzman and David Shiden - Green Project Management, CRC Press, 2010.

213CHE1105	Petroleum Refinery Engineering	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** Program Elective **Course Type:** Theory				

Course Objective(s):

To acquire basic knowledge in separation of products from crude and its various applications as fuel in major engineering sectors.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Explain Petroleum refining and thermal cracking processes

CO2: Detail Catalytic cracking and catalytic reforming processes

CO3: Produce fuels such as aviation gasoline, motor fuel, kerosene, jet fuel

CO4: Manufacture lubricating oil

CO5: Store and transport petroleum product.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1			H		H				L			
CO2												
CO3	L		M									
CO4					H							
CO5		H										

UNIT 1: Introduction **9 Hours**

Introduction- Origin, occurrence of petroleum, elementary ideas of gas and liquid reservoirs - Petroleum refining processes- General processing, topping and vacuum distillations - Thermal cracking in vapor, liquid and mixed phase - Thermal reforming and poly forming.

UNIT 2: Catalytic cracking **9 Hours**

Catalytic cracking- Fixed bed, fluidized bed, T.C.C - Houder flow etc., - Catalytic reforming - Conversion of petroleum gases into motor fuel with special reference to alkylation polymerization, hydrogenation and dehydrogenation - Blending of petroleum products.

UNIT 3: Production of various fuels **9 Hours**

Production - Aviation gasoline, motor fuel, kerosene, diesel oil, tractor fuel and jet fuel, hydrodesulphurization.

UNIT 4: Lubricating oil **9 Hours**

Lubricating oil manufacture - Vacuum distillation, solvent extraction and uses of lubricating oil - Petroleum waxes and asphalts - Elementary study of multi component distillation as applied to petroleum industry.

UNIT 5: Storage and transportation of petroleum products **9 Hours**

Octane number, Cetane number, Diesel index, their determination and importance - Storage of petroleum products tanks, bullets, special types of spheres etc., - Transportation of petroleum products road, rail, sea and pipeline - Importance of pipe line transportation.

Total: 45 Hours

Textbook(s):

1. R. A. Meyers, Handbook of Petroleum Refining Processes, McGraw Hill New York, 2013 (6^{th} Edition).

2. B. K. Bhaskara Rao, Modern Petroleum Refining Process, Oxford and IBH, New Delhi, 2015 (7^{th} Edition).

Reference(s):

1. G. D. Hobson, and W. Pohl, Modem Petroleum Technology, Gulf Publishers, 2007 (6^{th} Edition).

2. W. L. Nelson, Petroleum Refinery Engineering- McGraw Hill New York, 2013 (6^{th} Edition).

213CHE1106	Process Instrumentation	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** Program Elective **Course Type:** Theory				

Course Objective(s):

In process industry we need to measure the various parameters like pressure, temperature, flow, level etc., in a closed place where the process fluids are present in the industry. For this purpose, we need to study the instruments used to measure these parameters. This course discusses about the response of instruments and the knowledge about measurement of these parameters.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Analyze the response of instruments.

CO2: Ability to integrate knowledge about the instrument used for Temperature.

CO3: Ability to assimilate the facts about instruments used for pressure.

CO4: Analyze the different flow of fluids based on its Concentration.

CO5: Evaluate the supporting process and its effects.

Mapping of course outcomes:

CO/PO	**PO**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
CO1				M				L				
CO2		L		M	H							
CO3				M	H							
CO4	H						L					
CO5		M		L								

UNIT 1: Principles of Measurement **9 Hours**

Analysis: Measurement of Force, Strain and Torque - Use of strain gauges. Transducers - Resistive, Capacitive, Inductive and Piezoelectric pickups. Static and Dynamic response of Instruments. Errors in measurements.

UNIT 2: Temperature Measurement **9 Hours**

Liquid filled, Gas filled and Vapour pressure Thermometers. Bimetallic and Resistance thermo meters. Thermocouples and Thermistors. Optical and Radiation pyrometers.

UNIT 3: Pressure Measurement **9 Hours**

Manometers, Bourdon gauge and Bellows gauge. Measurement of pressure and Vacuum. Use of Transducers

UNIT 4: Flow, Density and Level Measurements **9 Hours**

Variable head flow meters. Area flow meter s. Positive displacement meters. Pressure Probes. Level measurements - Direct and Inertial types. Measurement of density and specific gravity. Instruments for weighing and feeding.

UNIT 5: Miscellaneous Measurements **9 Hours**

Analysis of gas mixtures. Thermal conductivity, Viscosity and Electrical conductivity. Supporting instrumentation - Standard cells, Gas Sensors, PH Measurement, Principles of Telemetering. P and I diagram.

Total: 45 Hours

Textbook(s):

1. D. P. Eckman, Industrial Instrumentation, Wiley - Eastern, New Delhi, 2006.

2. R.K. Jain, Mechanical and Industrial Measurements, Khanna Publishers, New Delhi, 2011 (9th Edition).

Reference(s):

1. R. H. Perry, and D. W. Green, Perry's Chemical Engineer's Handbook, McGraw Hill (ISE), 2007 (8th Edition).

2. D. N. Considine, Process Instruments and Controls Handbook, McGraw Hill New York, 1997 (5th Edition).

3. R.P. Benedict, Fundamentals of temperature, Pressure and Flow measurements, John Wiley, New York, 1984 (3rd Edition).

4. B. E. Notlingk, Jones' Instrument Technology, Vol. I and II, ELBS, 1987 (4th Edition).

5. D. Patranabis, Principles of Instrumentation, Tata McGraw Hill New Delhi, 2007, (2nd Edition).

213CHE1107	Colloids and Surface Science	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** Program Elective **Course Type:** Theory				

Course Objective(s):

This course introduces the fundamentals of colloids and nanoparticle science, wherever possible applications of these concepts will be discussed.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: To provide the basic forces and Theories in collision.

CO2: To analyze the role of Surface Chemical Models.

CO3: To understand the role of Electric double coating hypothesis.

CO4: To Analyze the Stabilization of particles with non-ionic polymers and interpolate with models.

CO5: To Understand the dispersing power of polyelectrolyte and its activity.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H											
CO2	M				M							
CO3			H	M								
CO4				H								
CO5				M	M							

UNIT 1: Introduction **9 Hours**

Hamaker's analysis for interparticle attractive forces, Experiments verifying van der Waals interactions between surfaces, Lifshitz macroscopic theory for the Hamaker constant, Parsegian, Ninham's approximation to Lifshitz theory, Casimir and Polder's correction for relaxation effects, Example calculations of Hamaker constants for several specific metal, polymer, and ceramic systems, the influence of other types of interparticle forces.

UNIT 2: Hierarchy of Surface Chemical Models **9 Hours**

The hierarchy of surface chemical models for surface charging - Monoprotic surface charging systems Lattices and Organic acids, Metallic and Non-metallic, Oxide Systems - The role of surface oxygen in dictating surface charge for metal and non-oxide ceramic systems.

UNIT 3: Electric Double Layer **9 Hours**

The isolated electric double layer - Overlap of the double layer for interacting particles, free NRGs of isolated and interacting double layers, Repulsive NRG due to overlapping double layers - Derjaguin approximation for the interaction of spherical particles - Concept of the critical coagulation concentration, Influence of salt concentration, ionic strength, and ionic size - Influence of surface charge for monoprotic surface charge systems - The role of surface charging in the dispersion of solids in non-aqueous systems

UNIT 4: Stabilization of Particles with Non-Ionic Polymers **9 Hours**

Criteria for stabilization of particles with non-ionic polymers - The role of polymer solubility in stabilization-The role of co, and ter, polymers in providing stabilization reconciling surface attachment with polymer extension from the surface, the impenetrable barrier model for polymeric stabilization - The compression model by Bagchi for polymeric dispersion, the interpenetration and compression model for polymeric dispersion, Other assumptions with respect to the relative contribution of the Hamaker constant toward stabilization with polymers - Selection criteria for polymeric dispersants for specific types of material systems, Polymeric dispersion of nanometer size particles.

UNIT 5: Features of Polyelectrolyte **9 Hours**

Features of polyelectrolyte that contribute to their dispersing power - pKa, molecular size and distribution, type of polymer - Criteria for polyelectrolyte adsorption to charged surfaces - The role of pKa - Monitoring adsorption via solution depletion, EM scattering, and zeta potential measurements, polyelectrolyte conformation at charged surfaces – The combined electrostatic and impenetrable barrier model for dispersion of particles with polyelectrolytes - Some other concepts regarding "nonionic" dispersants in aqueous systems, interaction of polyelectrolytes with ionic species in solution.

Total: 45 Hours

Textbook(s):

1. P. C. Hiemenz, and Raj Rajagopalan., Principles of Colloids and Surface Chemistry, Marcel Dekker, New York, 1997.

2. De Keizer, Johannes Lyklema, and Hans Lyklema, Fundamentals of Interface and Colloid Science, Elsevier, New Delhi, 1995.

Reference(s):

1. A. J. Milling, Surface Characterization Methods, Principles, Techniques and Applications, (Surfactant Science Series- V, 87), CRC Press, New York, 1999.

213CHE2104	Multiphase Flow	L	T	P	C
		3	0	0	3

Prerequisite: Fluid Mechanics **Course Category:** Program Elective

Course Type: Theory

Course Objective(s):

This course introduces the fundamental concepts, principles and application of multiphase flow. The course opens with real life examples of such flow and its importance in process industries.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: To Provide general introduction to the theory of multiphase flow

CO2: To understand the dynamics of two phase flow

CO3: To Analyze the problems involved in multiphase flow dynamics.

CO4: Reinforce knowledge through practice with realistic problems

CO5: To provide the design, and develop the software programme in multiphase flow.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H	M	M	M	M							
CO2	M	H		M								
CO3	M	H	H	M								
CO4		M	M								M	
CO5				H	H							M

UNIT 1: Fluid-Solid Systems **9 Hours**

Fluid-Solid systems - Mobile and stagnant solids, Flow through porous media, Capillary Tube model, Application for flow through packed bed, filters, fluidized beds, Solid-Fluid Convening, Settling and Sedimentation, Fluid-Fluid systems - Flow patterns and flow regimes - Analysis of annular, stratified and bubble flow - Formation of bubbles and drops - Their size distribution and volume distribution.

UNIT 2: Two Phase Flow **9 Hours**

Two-phase co-current flow of gas liquid, Gas/Solid and Liquid/Liquid, Upward and Downward Flow in vertical pipes - Suspensions of sand, gravel coal etc., and their transport in horizontal Pipes - Drag reduction phenomena, Laminar, Turbulent, Creeping flow regimes - Suspension Rheology - Residence Time Distribution studies, Deterministic and stochastic flow system Models for chemical reactors, Prevention of circulatory flow - Role of draft tubes and wall baffles, Diffusion model and bubbling bed model for gas interchange and gas mixing - Axial mixing correlations.

UNIT 3: Theories of Intensity and Scale of Turbulence 9 Hours

Theories of intensity and scale of turbulence - Calculation of circulation velocities and power consumption in agitated vessels for Newtonian/ Non Newtonian fluids - Blending and Mixing of phases - Power required for aeration to suspend to an immiscible liquid or solids in Slurry reactors - Segregation phenomena - Prediction of optimum speed of impeller rotor and Design criteria for scale up.

UNIT 4: Bubble Size in Pipe Flow 9 Hours

Prediction of holdup and pressure drop of volume fraction, Bubble size in pipe flow, Lockhart - Martinelli parameters - Bubble Column and its Design aspects - Minimum carryover velocity, Holdup ratios, Pressure drop and transport velocities and their prediction.

UNIT 5: Flow through Porous Media of Composite Mixtures 9 Hours

Gas, Solid and Liquid composite slurries in horizontal and vertical pipes - Flow through Porous media of composite mixtures - Prediction of holdup, pressure drop and through put Velocities in 3 - Phase system –Design of multiphase contactors involving fluidization, pervaporation, lyophilisation and permeation for solids, liquids and gases - Design and Development of Software programmes in multiphase flow - Simulation in packed and fluidized beds and Stirred tank process equipment - Selection of equipment for gaseous, particulate and liquid effluents of various industries such as scrubbers, Stacks and Chimneys, Absorbers, Combustion devices, Electrostatic precipitators and filtration / reverse osmosis devices.

Total: 45 Hours

Textbook(s):

1. R. S. Brodkey, The Phenomena Of Fluid Motion, McGraw Hill, New York, 2004.

2. H. Schlichting, Boundary layer theory, Springer, London, 2006 (8^{th} Edition).

Reference(s):

1. Gad Hestsroni, Handbook of Multiphase systems, Hemisphere publishing Corporation, Washington, 1982.

2. G. W. Govier, and K. Aziz, The Flow of complex Mixture in Pipes, Van Nostrand Reinhold Co, New York, 1972.

3. G. B. Wallis, One Dimensional Two Phase Flow, McGraw Hill, New York,1969.

213CHE2105	Computer Aided Process Plant Design	L	T	P	C
		3	0	0	3
Prerequisite: Process Equipment Design and drawing	**Course Category:** Program Elective **Course Type:** Theory				

Course Objective(s):

To understand the use of computer aided tools for process plant design.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Evaluate transport properties and thermodynamic properties.

CO2: Develop basic model for Chemical Engineering Operations.

CO3: Develop CAD model for Fluid Moving Machinery.

CO4: Develop CAD model for Heat Transfer Equipment.

CO5: Develop CAD model for Mass Transfer Equipment.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H	M	M	M	M							
CO2	M	H		M								
CO3	M	H	H	M								
CO4		M	M								M	
CO5				H	H							M

UNIT 1: Introduction and Properties Evaluation **9 Hours**

Introduction and Properties Evaluation - Spread sheeting, hierarchy of process design and the Onion model Flow sheeting, typical unit of CAD system - Process Synthesis - Physical properties evaluationTransport properties and thermodynamic properties of gases and binary mixtures.

UNIT 2: Basic Model Development **9 Hours**

Basic model development for preliminary systems, methods of calculating vapour liquid equilibrium data for ideal and non-ideal mixtures, bubble point and dew point, flash and distillation calculations, equipment design, development of software progammes for the following systems, piping system - Single phase and two phases.

UNIT 3: Fluid Moving Machinery **9 Hours**

CAD Model for fluid moving machinery and storage design - Separator system - Two phase and three phase - Storage system - Atmospheric, pressurized cryogenics.

UNIT 4: Heat Transfer Equipment **9 Hours**

CAD model for heat transfer equipment design - Double Pipe, Shell and tube heat exchanger - PHE - Air cooler - Heat integration of evaporators.

UNIT 5: Mass Transfer Equipment **9 Hours**

CAD Model for mass transfer equipment and safety devices design - Binary mixtures - Pseudo binary, multistage distillation system - Heat integration of distillation columns - Absorber and strippers – Liquid-Liquid extractor - Safety devices - pressure safety valve and flare system.

Total: 45 Hours

Textbook(s):

1. B. C. Bhattacharyya, and C. M. Narayanan, Computer aided design of Chemical Process Equipment, New Central Book Agency (P) LTD, New Delhi, 1992 (1st Edition).

2. Robin Smith, Chemical Process Design, McGraw Hill, New York, 1995.

Reference(s):

1. A. Hussein, Chemical Process Simulation, Wiley, Singapore, 1986.

2. A. K. Coker, FORTRAN programme for chemical process design, analysis and Simulation, Gulf Publishing Co, 1995.

3. Y. A. McGee, and W. Robert E Peerly, Recent developments in chemical process and plant design, John Wiley, New York, 1987.

4. M. E. Leesley, Computer Aided Process Plant Design, Gulf Publishing Co,1982.

5. J. M. Douglas, Conceptual Design of Chemical Processes, McGraw Hill, New York, 1981.

213CHE1108	Fertilizer Technology For Chemical Engineers	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** Program Elective **Course Type:** Theory				

Course Objective(s):

Indian economy is dominated by agriculture sector. Synthetic fertilizers are must for producing good crops. Hence it is needed to provide comprehensive and balanced understanding of essential link between chemistry and the synthetic fertilizer industry. It is therefore vital for chemical engineers to understand for each fertilizer product, its flow diagram for Industry production.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Understand the global outlook of fertilizer resources.

CO2: Elaborate the production processes of nitrogenous fertilizers.

CO3: Understand the about phosphate fertilizer production.

CO4: Understand the production processes of NPK fertilizers.

CO5: Understand about the mixed fertilizers.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1		M										
CO2				H								
CO3			L									
CO4				H								
CO5							M					

UNIT 1: Global Outlook of Fertilizer Resources **9 Hours**

Role of organic manures and Chemical Fertilizers - Types of Chemical fertilizers, growth of fertilizer industry in India, their location, energy consumption in various fertilizer processes - materials of various fertilizer processes, materials consumption in fertilizer industry.

UNIT 2: Nitrogenous Fertilizers **9 Hours**

Feed stock for production of Ammonia, Natural gas, associated gas, Coke oven gas, Ammonium Sulphate, Ammonium Nitrate, Urea, Calcium Ammonia Nitrate, Ammonium chlorides - Methods of Production, characteristics and specification - Storage and handling.

UNIT 3: Phosphate Fertilizer **9 Hours**

Raw materials for the manufacture of Phosphate fertilizer - Phosphate Rock, Sulphur, Pyrites etc., - Processes for the production of Sulfuric and Phosphoric acid - Phosphate fertilizers, ground rock phosphate, bone meal, methods of production, characteristics and specifications for single super phosphate, triple super phosphate.

UNIT 4: NPK Fertilizers **9 Hours**

NPK Fertilizers - Methods of production, Characteristics and specifications for complex fertilizers, methods of production of Ammonia phosphate, Sulphate, Di-ammonium phosphate and Nitro phosphates – NPK Fertilizers - Urea, Ammonium Phosphate, Monoammonium Phosphate and various grades of NPK fertilizers produced in the country.

UNIT 5: Mixed Fertilizers **9 Hours**

Mixed fertilizers - Granulated mixtures - Bio fertilizers - Secondary and Micro Nutrients, Fluid Fertilizers - Controlled release fertilizers - Pollution from fertilizer industry - Solid, liquid and gaseous pollution standards.

Total: 45 Hours

Textbook(s):

1. A. V. Slack. Chemistry and Technology of Fertilizers – Inter Science, New York, 2005.

2. M. E. Pozin, Fertilizer Manufacture, MIR Publishers, Moscow, 2006.

Reference(s):

1. L. J. Carpentire, New Developments in Phosphate Fertilizer Technology, Elsevier, New Delhi, 2001.

2. Strelzoff, Technology and Manufacture of Ammonia, John Wiley and Sons, New York, 2004 (8^{th} Edition).

213CHE1109	Environmental Engineering	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** Program Elective **Course Type:** Theory				

Course Objective(s):

To understand the basic water quality criteria and standards, and their relation to public health and requirement distribution of water quality.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: An insight into the structure of drinking water supply systems.

CO2: Ability to Including water transport, treatment and distribution.

CO3: An understanding of water quality criteria and standards, and their relation to public health.

CO4: Ability to design and evaluate water supply project alternatives on basis of chosen selection criteria.

CO5: Requirement distribution of water quality.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1			H		M							
CO2						H		L				
CO3		M		H			L					
CO4							H		M			
CO5		H			M					L		

UNIT 1: Planning for Water Supply System **9 Hours**

Public water supply system -Planning – Objectives -Design period – Population forecasting Water demand - Sources of water and their characteristics -Surface and Groundwater- Impounding Reservoir Well hydraulics - Development and selection of source – Water quality – Characterization and standards- Impact of climate change.

UNIT 2: Conveyance System **9 Hours**

Water supply -intake structures -Functions and drawings -Pipes and conduits for water- Pipe materials – Hydraulics of flow in pipes -Transmission main design -Laying, jointing and testing of pipes – Drawings appurtenances – Types and capacity of pumps -Selection of pumps and pipe materials.

UNIT 3: Water Treatment **9 Hours**

Objectives –Unit operations and processes – Principles, functions design and drawing of Chemical feeding, Flash mixers, flocculators, sedimentation tanks and sand filters – Disinfection- Residue Management - Construction and Operation & Maintenance aspects of Water Treatment Plants.

UNIT 4: Advanced Water Treatment **9 Hours**

Principles and functions of Aeration – Iron and manganese removal, Defluorination and demineralization - Water softening – Desalination – Membrane Systems – Recent advances.

UNIT 5: Water Distribution and Supply to Buildings **9 Hours**

Requirements of water distribution - Components -Service reservoirs -Functions and drawings - Network design - Economics - Computer applications - Analysis of distribution networks -Appurtenances - operation and maintenance - Leak detection, Methods. Principles of design of water supply in buildings - House service connection -Fixtures and fittings - Systems of plumbing and drawings of types of plumbing.

Total: 45 Hours

Textbook(s):

1. S. K. Garg, Environmental Engineering-Vol.1, Khanna Publishers, New Delhi, 2005.

2. P. N. Modi, Water Supply Engineering-Vol. I, Standard Book House, New Delhi, 2005.

3. B. C. Punmia, Ashok K. Jain, and Arun K. Jain, Water Supply Engineering, Laxmi Publications Pvt Ltd, New Delhi, 2005.

Reference(s):

1. Government of India, Ministry of Urban Development, Manual on Water Supply and Treatment, CPHEEO, New Delhi, 2003.

2. Syed R. Qasim, Edward M. Motley, and Guang Zhu, Water Works Engineering Planning - Design and Operation, Prentice Hall of India Private Limited, New Delhi, 2006.

213CHE1110	Chemical Process in Pulp and Paper Technology	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** Program Elective **Course Type:** Theory				

Course Objective(s):

To increase awareness of the factors that drive industry trends and to review industry statistics about the major grades of paper and board.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Apply basic concepts of pulp and paper technology to produce paper.

CO2: Apply reactions and unit operations steps to manufacture pulp.

CO3: Apply reactions and unit operations steps appropriately in manufacturing of paper.

CO4: Apply reactions and unit operations appropriately in manufacturing cellulose and various lignin chemicals.

CO5: Apply waste disposal techniques.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	L		H	M								
CO2	L		H	M	M							
CO3		H	M			L						
CO4				H								
CO5	M		L			H						

UNIT 1: Basics of Pulp and Paper Technology **9 Hours**

Describe the consumption pattern of different types of paper, describe cellulose raw material, identify problems and scope in India.

UNIT 2: Pulp **9 Hours**

Explain various raw materials. Differentiate the various pulping processes; describe the Kraft pulping process with flow diagram. Compare various types of pulps, Explain chemical recovery process.

UNIT 3: Paper **9 Hours**

Differentiate the features f various raw materials used in paper manufacture, describe the Wet process for paper Manufacture with flow diagram Describe Fourdrinier machine, and describe the economics in paper industry.

UNIT 4: Cellulose and Lignin Chemicals **9 Hours**

Describe the properties of cellulose, prepare chemical cellulose, Describe the characteristics of Lignin chemicals, Selection of cellulose and lignin chemicals.

UNIT 5: Waste Disposal Techniques **9 Hours**

Analyze pollution potentials of Indian pulp and paper industry, apply bio-technical approach for pollution, Apply Lignin waste treatment.

Total: 45 Hours

Textbook(s):

1. M. Gopala Rao and Marshall Sittig - Dryden's Outlines of Chemical Technology - East-West Pvt Ltd., New Delhi, 1997 (3rd Edition).

2. George T. Austin, Shreve's Chemical Process Industries - McGraw-Hill International, Singapore, 2017 (5th Edition).

Reference(s):

1. S. C. Bhatia, Environmental Pollution and Control in Chemical Process Industries, Khanna Publishers, 2011 (2nd Edition)

2. R. K. Trivedi, Pollution Management in Industries, Environmental Publication, Karad, India, 2009.

213CHE1111	Electrochemical Engineering	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** Program Elective **Course Type:** Theory				

Course Objective(s):

The objective of this course is to acquire fundamental knowledge of electrochemistry/ electrochemical engineering including electro kinetic phenomena. The knowledge is applied to understand general methodologies for analysis and design of electrochemical systems.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Understand basic laws of Electrochemical Processes.

CO2: Apply Mass transfer over Electrochemical Reaction.

CO3: Understand the Metallic Surface against corrosion

CO4: Understand about primary and secondary batteries

CO5: Apply metal finishing techniques.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H	M							L			
CO2			H	L								
CO3	H				H			M		M		L
CO4					H		L					
CO5			H									

UNIT 1: Introduction **9 Hours**

Introduction - Faraday's law, Nernst potential, galvanic cells, polarography - Electrical double layer, its role in electrochemical processes, electro capillary curve, Helmholtz layer, Guoy-Steven's layer, fields at the interface.

UNIT 2: Diffusion Controlled Electrochemical Reaction **9 Hours**

Diffusion controlled electrochemical reaction, the importance of convection and the concept of limiting current - Mass transfer over potential or concentration polarization - Secondary current distribution - Rotating disc electrode.

UNIT 3: Introduction of Metallic Surface Preparation **9 Hours**

Metallic surface preparation - Phosphating - Inhibitors in acid media - Engine cooling systems – Control measures - Industrial boiler water corrosion control - Protective coatings- Vapor phase inhibitors - Cathodic protection- Sacrificial anodes - Paint removers.

UNIT 4: Primary and Secondary Batteries **9 Hours**

Primary and Secondary Batteries - Lechlanche dry cell, Alkaline manganese cell, mercury cell, air depolarized cell, sea, water cell, reserve electrolyte cells like Mg, $CuCl_2$, Zn, PbO, Secondary cells like lead acid, Ni, Cd, Ni, Fe, AgO, Zn, Cd, Sodium, Sulphur, Li, S, Fuel cells.

UNIT 5: Metals and Metal Finishing **9 Hours**

Metals - Graphite, lead dioxide, titanium substrate insoluble electrodes, iron oxide, semi conducting type etc., -Metal finishing - Electrodeposition, electro refining, electroforming, electro polishing, anodizing, selective solar coatings.

Total: 45 Hours

Textbook(s):

1. John Newman, Electrochemical Systems, Wiley-Inter Science, New York, 2004 (3rd Edition).

2. A. Geoffrey, Electrochemical Engineering Principles, Prentice Hall, New Jersey, 2007 (3rd Edition).

3. H. Wendet and G. Kreysa, Electrochemical science and technology in chemical and other industries, Springer, London, 2004 (2nd Edition).

Reference(s):

1. C. Mantle, Electrochemical Engineering, McGraw Hill, New York, 2006 (3rd Edition).

2. A. T. Kuhn, Industrial Electrochemical Process, Elsevier, New Delhi, 2008(2nd Edition).

3.Ewald Heitz and Gerhard Kreysa, Principles of Electrochemical Engineering - VCH publishers, 2001(2nd Edition).

4. T. Z. Fahidy, Principles of Electrochemical Reactor Analysis, Elsevier, New Delhi,

2005 (3rd Edition).

213CHE1112	Chemical Process Plant Safety	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** Program Elective **Course Type:** Theory				

Course Objective(s):

This course fully examines the diverse regulatory, design and operational issues related to process plant safety and will develop the arsenal of proven tools and techniques for implementing safety and risk management in various segments of the CPI.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Understand the Indian and International Safety standards.

CO2: Analyze the causes of accident and explain various engineering control methods.

CO3: Understand the storage, handling and transportation of hazardous materials.

CO4: Understand the fire extinguishing agents and methods.

CO5: Understand the risk assessment methods.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	M						L					
CO2			H									
CO3		H			M							
CO4			H									
CO5			H	L		M						

UNIT 1: Introduction to Industrial Safety and Hazards 9 Hours

Describe importance of safety in Industry; classify the hazards, Explain Indian and International safety standards.

UNIT 2: Chemical Hazards and Their Control 9 Hours

Classify chemical hazards & their control, explain occupational diseases and poisoning, apply preventive measures of diseases, describe safety aspects in plant layout, different color codes for chemical plants, describe safety aspects in plant layout, Identify different color codes for chemical plants.

UNIT 3: Safe Handling of Hazardous Chemicals and Risk Assesment 9 Hours

Discuss characteristics of hazardous chemicals, handle hazardous chemicals for Storage, Handling & Transportation, Explain hazard identification methods, Hazard identification methods, List risk assessment methods, Explain risk assessment methods

UNIT 4: Fire Hazards and Their Prevention 9 Hours

Describe Fire hazards; List the causes of Fire hazards, explain fire triangle, describe Classes of fire, describe fire extinguishers, and List types of extinguishers, describe Construction and working of fire extinguishers, describe Methods of their applications for fire extinguishers.

UNIT 5: Accidental investigations and case studies 9 Hours

Learning from Accidents, Layered Investigations, Investigation Process, Investigation Summary, Aids for Diagnosis and recommendations. Case histories on static electricity, chemical reactivity and system design.

Total: 45 Hours

Textbook(s):

1. D. Venkateswarlu, K. R. Upadrashta, and K. D. Chandrasekaran, Manual of Chemical Technology - Chemical Engineering Education Development Centre, IIT Madras, 2012.

2. K.U. Mistry, Fundamentals of Industrial Safety and Health, Ahmedabad Siddharth Prakashan, 2012 (3rd Edition).

3. Daniel A. Crowl and Joshef F. Louvar, Chemical Process Safety: Fundamentals with application, Prentice Hall, 2011(3rd Edition).

Reference(s):

1. N. K. Tarafdar, K. J. Tarafdar and Dhanpatrai Co.Ltd, Industrial Safety Management, New-Delhi, 2012 (1st Edition).

2. L. M. Deshmukh, Industrial safety management, Tata McGraw Hill, New Delhi, 2006.

213CHE2106	Design of Multicomponent Separation Processes	L	T	P	C
		3	0	0	3
Prerequisite: Mass Transfer I	**Course Category:** Program Elective **Course Type:** Theory				

Course Objective(s):

To understand the design of multicomponent separation processes.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Describe the multicomponent separation process.

CO2: Analyze and interpret the data using various methods.

CO3: Design equipment for various separation processes.

CO4: Explain the concepts of various separation processes.

CO5: Calculate the process economy.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H	H		H								
CO2	H			H								
CO3			H	M	H							
CO4					H							
CO5	H							L	L			

UNIT 1: Introduction **9 Hours**

Overview of multi-component separation. Non-ideal solution and properties, equation of state, vapor liquid equilibrium.

UNIT 2: Multicomponent separation **9 Hours**

Short cut method, rigorous calculations -sum rate, boiling point and Newton's methods, inside-out method for designing of multi-component distillation, absorption and extraction column / contacting devices.

UNIT 3: Column design **9 Hours**

Choice of column: tray, random packing and structured packing- Design of adsorption and ion exchange column.

UNIT 4: Separation techniques **9 Hours**

Crystallization, Affinity separation and chromatographic separation- principle- applications

UNIT 5: Process Economy **9 Hours**

Optimal reflux ratio (recycle stream) - operating expenditure versus capital expenditure for all types of columns and contacting devices

Total: 45Hours

Textbook(s):

1. C. D. Holland, Fundamentals and Modeling of Separation Processes, Prentice Hall, 2016 (1^{st} edition).

2. W. L. Luyben, Process Modeling Simulation and Control for Chemical Engineers, McGraw Hill, New York, 1990 (2^{nd} edition).

Reference(s):

1. K. Najim K, Process Modeling and Control in Chemical Engineering, CRC Press, 1990 (1^{st} edition).

2. R. Aris, Mathematical Modeling, A Chemical Engineering Perspective (Process System Engineering), Academic Press, 1999 (1^{st} edition).

.

213CHE1113	Fundamentals of Computational Fluid Dynamics	L	T	P	C
		3	0	0	3

Prerequisite: Fluid dynamics

Course Category: Program Elective

Course Type: Theory

Course Objective(s):

To impart knowledge about the applications of computation fluid dynamics (CFD) to various engineering problems.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Apply equations of fluid flow and heat transfer for turbulence models

CO2: Apply finite difference, finite volume and finite element methods to fluid flow problems

CO3: Apply finite volume to solve fluid flow problems

CO4: Analyze issues surrounding two-phase flow modeling

CO5: Analyze grid generation.

Mapping of course outcomes:

CO/PO	PO											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
CO1	M		H		L							
CO2			H									
CO3		M		L								
CO4			H									M
CO5					L	M						

UNIT 1: Conservation Laws and Turbulence Models 9 Hours

Governing equations of fluid flow and heat transfer –mass conservation, momentum and energy equation, differential and integral forms, conservation and non-conservation form. Characteristics of turbulent flows, time averaged Navier Strokes equations, turbulence models-one and two equations, Reynolds stress, LES and DNS.

UNIT 2: Finite Difference Approximation 9 Hours

Mathematical behavior of PDE, finite difference operators, basic aspects of discretization by FDM, explicit and implicit methods, error and stability analysis.

UNIT 3: Finite Volume Method **9 Hours**

Diffusion problems – explicit and implicit time integration; Convection-diffusion problems – properties of discretization schemes, central, upwind, hybrid, QUICK schemes; Solution of discredited equations.

UNIT 4: Flow Field Computation **9 Hours**

Pressure velocity coupling, staggered grid, and SIMPLE algorithm, PISO algorithm for steady and unsteady flows.

UNIT 5: Grid Generation **9 Hours**

Physical aspects, simple and multiple connected regions, grid generation by PDE solution, grid generation by algebraic mapping.

Total: 45 Hours

Textbook(s):

1. J. D. Anderson Jr, Computational Fluid Dynamics: The Basics with Applications, McGraw Hill, New York, 1995.

2. K. Muralidhar and T. Sundararajan, Computational Fluid Flow and Heat Transfer, Narosa Publishing House, 2009 (1st edition).

Reference(s):

1. J. H. Ferziger and M. Peric, Computational Methods for Fluid Dynamics, Springer, 2002 (3rd edition)

2. V. V. Ranade, Computation Flow Modeling for Chemical Reactor Engineering- Academic Press, 2001(1st edition).

213CHE1114	Bioprocessing and Bioseparations	L	T	P	C
		3	0	0	3

Prerequisite: Nil

Course Category: Program Elective
Course Type : Theory

Course Objective(s):

To study various unit operations and analytical techniques involved in bioprocess

Course Outcomes(s):

At the end of the course the students would be able to

CO1: understand various unit operations involved in upstream and downstream processes

CO2: describe the analytical method used for the production of biotech products

CO3: optimize the biological processes

CO4: scale up different unit operations

CO5: validate the industrial process

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	M	H										
CO2					H							
CO3	H	H		H								
CO4	M		H	H					L	L		
CO5			H	H					L	L		

UNIT 1: Unit Operations **9 Hours**

Introduction to the different unit operations utilized in production of biotech drugs in the areas of upstream processing, harvest, and downstream processing.

UNIT 2: Analytical methods **9 Hours**

Introduction to analytical methods used for characterization of biotech products and processes (high performance liquid chromatography, mass spectrophotometry, capillary electrophoresis, near infrared spectroscopy, UV spectroscopy).

UNIT 3: Process Optimization **9 Hours**

Optimization of biotech processes - unit operation specific optimization vs. process optimization, process intensification, statistical data analysis.

UNIT 4: Scale up of unit operations **9 Hours**

Scale-up of different unit operations utilized in bioprocessing: procedures, issues that frequently occur and possible solutions

UNIT 5: Good Manufacturing Practices (GMP) 9 Hours

Need, principles and key practical issues. Process validation: basics, planning and implementation. Industrial case studies in bioprocessing. Current topics in bioprocessing and bioseparations: Quality by Design and Process Analytical Technology.

Total: 45 Hours

Textbook(s):

1. M. L. Shuler, and F. Kargi, Bioprocess Engineering-Basic Concepts, Prentice Hall Pvt. Ltd., New Delhi- 2018 (3^{rd} Edition).

2. P. Stanbury, A. Whitaker, and S. Hall, Principles of Fermentation Technology, Elsevier (An Imprint of Butterworth-Heinemann), 2016 (3^{rd} Edition).

Reference(s):

1. P. M. Doran, Bioprocess Engineering Principles - Academic Press (An Imprint of Elsevier) New Delhi- 2013 (2^{nd} Edition).

2. J. E. Bailey, and D. F. Ollis, Biochemical Engineering Fundamentals - McGraw Hill, New Delhi- 2004 (2^{nd} Edition).

213CHE1115	Membrane Science and Engineering	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category: Program Elective** **Course Type : Theory**				

Course Objective(s):

Students will gain the knowledge on basic principles of membrane process; design membrane modules for reverse osmosis, ultracentrifugation and gas separation process; and understand the various applications of membranes in medical field.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Understand the principles of different membrane manufacturing methods.

CO2: Ability to select suitable materials for membrane separation.

CO3: Able to design a suitable membrane separation process for the liquid stream.

CO4: Gain knowledge of membrane capabilities and constraints in the aspects of engineering.

CO5: Understand the principles and application of reverse osmosis, microfiltration, and ultrafiltration.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1			M									
CO2			M	M								
CO3				M		H						
CO4			H	M	M							
CO5			H		L		L					

UNIT 1: Membranes - Introduction 9 Hours

Introduction, classification, membrane processes, principle, theory, membranes and materials, membrane selectivity, modules, concentration polarization, membrane fouling and cleaning, applications.

UNIT 2: Membranes models and governing equations 9 Hours

Mechanism of membrane transport, RO/UF transport, solution diffusion model, dual sorption model, free volume theory, pore flow model, resistance model, boundary layer film model, membrane modules, flat, cartridge, spiral wound, tubular, hollow fiber, design equations, applications.

UNIT 3: Membrane Preparation **9 Hours**

Membrane preparation techniques-isotropic membranes, anisotropic membranes, metal membranes, ceramic membranes, liquid membranes and biomembranes.

UNIT 4: Membrane Gas separation **9 Hours**

pervaporation and gas separation, principle, theory, process design, applications, complete mixing model (binary and multi component) for gas separation, cross flow model, counter current flow model.

UNIT 5: Membrane Gas-Liquid separation **9 Hours**

Engineering aspects of membranes, cascade operation, examples of cascade operation, design of gaseous & liquid diffusion membrane module. Hybrid membrane techniques, membrane reactor, membrane distillation, membrane extraction and osmotic distillation, design equations, applications.

Total: 45 Hours

Textbook(s):

1. Christie J. Geankoplis, Transport Processes and Unit Operations, Prentice Hall of India Pvt. Ltd., New Delhi, 1997 (3rd Edition).

2. Sun, Tak, Hwang and Karl Kammermayer, Membranes in Separations, John Wiley and Sons, New York, 1975.

3. Richard W. Baker, Membrane Technology and Applications, John Wiley & Sons Inc., 2004.

4. J. D. Seader and Ernest J. Henley, Separation Process Principles, John Wiley & Sons, 2006.

Reference(s):

1. J. M. Coulson and Richardson, Chemical Engineering: – Particle Technology and Separation Processes Vol.2, Asian Books Pvt. Ltd., New Delhi, 1998 (4th Edition).

2. L. Warren, McCabe, Julian Smith and Peter Harriot, Unit Operations of Chemical Engineering, Tata McGraw Hill, 2004 (6th Edition).

3. C. Judson King, Separation Processes, McGraw Hill Inc, 1980.

4. E. J. Hoffman, Membrane separations Technology: single, stage, Multistage, and Differential Permeation, Gulf Professional Publishing, 2003.

213CHE1116 Electrochemical Conversion and Storage Devices	L	T	P	C
	3	0	0	3
Prerequisite: Nil	**Course Category: Program Elective** **Course Type : Theory**			

Course Objective(s):

This course will introduce electrochemical concepts relevant to real-world devices such as electrochemical energy storage devices, photo electrochemical energy conversion devices, and solid state electrochemical devices such as sensors. Basic electrochemical principles with an emphasis on solid state electrochemistry and the nature of the solid-electrolyte interface will be discussed, in order to give students, the background knowledge needed for understanding and analyzing real device performance.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Understand the principles of electrochemical systems, thermodynamics and kinetics.

CO2: Understand the different battery storage systems.

CO3: Understand the different solar cell conversion systems.

CO4: Understand the different supercapacitor storage systems.

CO5: Understand the different fuel cell and electrochemical sensors systems.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1		M	M	L	L	L	L					
CO2			M	M	M							
CO3			M	M		H						
CO4			H	M	M							
CO5			H	M	L		L					

UNIT 1: Introduction **9 Hours**

General definitions of electrochemical systems, equilibrium and non-equilibrium phenomena in electrochemistry, electrochemical kinetics, energy devices in electrochemistry and its principles.

UNIT 2: Batteries **9 Hours**

Primary and secondary batteries, limitations of battery, performance, Lead Acid Battery, Nickel-Metal Hydride (Ni-MH), Rechargeable Batteries, Lithium-Ion Rechargeable Batteries, Liquid-Redox Rechargeable Batteries.

UNIT 3: Solar Cell **9 Hours**

Construction and working principle, Classification, limitation of solar cells, Materials for electrodes and electrolyte, Transport properties.

UNIT 4: Electrochemical Supercapacitors **9 Hours**

Construction and working principle, Classification, limitation of supercapacitors, Materials for electrodes and electrolyte, Transport properties.

UNIT 5: Fuel Cell and Electrochemical Sensors **9 Hours**

Types of Fuel Cells, Proton Exchange Membrane Fuel Cells, Solid Oxide Fuel Cells, Electrochemical sensors: introduction, Construction and working principle, Classification.

Total: 45 Hours

Textbook(s):

1. Jiujun Zhang, Lei Zhang, Hansan Liu, Andy Sun, and Ru-Shi Liu, Electrochemical Technologies for Energy Storage and Conversion, Wiley-VCH, 2011 (1st edition).

2. Hubert H. Girault, Analytical and Physical Electrochemistry, EFPL Press, 2004.

3. Ryan O'Hayre, Suk-Won Cha, Whitney Colella, and Fritz B. Prinz, Fuel Cell Fundamentals, Wiley, 2009 (2nd edition).

Reference(s):

1. Allen J. Bard, and Larry R. Faulkner, Electrochemical Methods: Fundamentals and Applications, John Wiley & Sons, 2001(2nd edition).

2. John O'M. Bockris, Amulya K.N. Reddy, and Maria E. Gamboa-Aldeco, Modern Electrochemistry 2A: Fundamentals of Electrodics, Springer; 2001 (2nd edition).

213CHE1117 Hydrogen Energy and Fuel Cell Technology	L	T	P	C
	3	0	0	3

Prerequisite: Nil **Course Category: Program Elective**

Course Type : Theory

Course Objective(s):

To teach students fundamentals required in the development of hydrogen and fuel cell technology. Thermodynamics, chemical reaction engineering, transport processes and electrochemical engineering will be covered in the perspective of fuel cell technology. Source of hydrogen and hydrogen generation processes including storage and transportation will be covered.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Understand the principles of fuel cells.

CO2: Cognize fuel cell kinetics and transport properties.

CO3: Comprehend the characterization technics of fuel cells.

CO4: Understand the principles of hydrogen energy.

CO5: Understand the principles of cost, life cycle analysis of fuel cell process.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1		M	M	L	L	L	L					
CO2			M	M	M							
CO3		L	M	M		H						
CO4			H	M	M							
CO5			H	M	L		L				L	M

UNIT 1: Introduction **9 Hours**

Overview of fuel cells: Low and high temperature fuel cells; Fuel cell thermodynamics - heat, work potentials, prediction of reversible voltage, fuel cell efficiency.

UNIT 2: Fuel Cell Kinetics and Transport Properties **9 Hours**

Fuel cell reaction kinetics - electrode kinetics, overvoltages, Tafel equation, charge transfer reaction, exchange currents, electrocatalyses - design, activation kinetics, Fuel cell charge and mass transport - flow field, transport in electrode and electrolyte.

.

UNIT 3: Fuel cell characterization **9 Hours**

In-situ and ex-situ characterization techniques, i-V curve, frequency response analyses; Fuel cell modeling and system integration: - 1D model – analytical solution and CFD models.

UNIT 4: Hydrogen Energy **9 Hours**

Introduction, Green Hydrogen, Liquid and Compressed Hydrogen, Hydrogen Production, Hydrogen Storage, Hydrogen Storage Materials.

UNIT 5: Cost, Life Cycle Analysis **9 Hours**

Balance of plant, Hydrogen production from renewable sources and storage, safety issues, cost expectation and life cycle analysis of fuel cells.

Total: 45 Hours

Textbook(s):

1. M. M. Mench, Fuel Cell Engines, Wiley, 2008.

2. M. T. M. Koper, Fuel Cell Catalysis, Wiley, 2009.

3. J. O. Bockris, and A. K. N. Reddy, Modern Electrochemistry, Springer 1998.

4. J. Larminie, and A. Dick, Fuel Cell Systems Explained, Wiley, 2003 (2nd Edition).

Reference(s):

1. R. O'Hayre, S. W. Cha, W. Colella, and F. B. Prinz, Fuel Cell Fundamentals, Wiley, New York, 2006.

2. A. J. Bard, and L. R Faulkner, Electrochemical Methods, Wiley, New York 2004.

3. S. Basu, Fuel Cell Science and Technology, Springer, New York 2007.

4. H. Liu, Principles of fuel cells, Taylor & Francis, New York 2006.

213CHE1118	Air Pollution Control Engineering	L	T	P	C
		3	0	0	3

Prerequisite: Nil	**Course Category: Program Elective** **Course Type : Theory**

Course Objective(s):

To understand the air pollution effect, air quality and monitoring.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Understand about effects of air pollution.

CO2: Understand the sampling of the pollutants.

CO3: Understand about air pollution system.

CO4: Understand about air Quality.

CO5: Understand about air pollution control.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1		M	H									
CO2							H					
CO3			H									
CO4				M								
CO5				H								

UNIT 1: Introduction **9 Hours**

Structure and composition of Atmosphere – Definition, Scope and Scales of Air Pollution – Sources and classification of air pollutants and their effect on human health, vegetation, animals, property, aesthetic value and visibility- Ambient Air Quality and Emission standards.

UNIT 2: Meteorology **9 Hours**

Effects of meteorology on Air Pollution – Fundamentals, Atmospheric stability, Inversion, Wind profiles and stack plume patterns- Atmospheric Diffusion Theories – Dispersion models, Plume rise.

UNIT 3: Control of Particulate Containments **9 Hours**

Factors affecting Selection of Control Equipment – Gas Particle Interaction – Working principle – Gravity Separators, Centrifugal separators Fabric filters, Particulate Scrubbers, Electrostatic Precipitators.

UNIT 4: Control of Gaseous Containments **9 Hours**

Factors affecting Selection of Control Equipment – Working principle – absorption, Adsorption, condensation, Incineration, Bio filters – Process control and Monitoring.

UNIT 5: Air Pollution control **9 Hours**

Sources, types and control of indoor air pollutants, sick building syndrome and Building related illness- Sources and Effects of Noise Pollution – Measurement – Standards –Control and Preventive measures.

Total: 45 Hours

Textbook(s):

1. Louis Theodore, Air Pollution Control Equipment Calculations, Wiley-Inter Science, 2010 (1^{st} Edition).

2. C. D. Cooper and F. C. Alley, Air Pollution Control: A Design Approach, Waveland Pr Inc., 2010 (4^{th} Edition).

3. Noel de nevers, Air Pollution Control Engineering, Waveland Pr Inc., 2016 (3^{rd} Edition).

Reference(s):

1. M. N. Rao, and H. V. N. Rao, Air Pollution, McGraw Hill Education, 2017 (1^{st} Edition).

2. Anjaneyulu Yerramilli, Air pollution: Prevention and Control Technologies, BS Publications, 2020 (2^{nd} Edition).

213CHE1119	Fine Chemicals Technology	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category: Program Elective** **Course Type : Theory**				

Course Objective(s):

The course covers the chemical process industries, which is the integral part of the chemical sciences and engineering. It mainly covers the synthesis, industrial manufacture, flow diagram, properties and uses of fine chemicals.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Understand heavy and fine chemical industries.

CO2: Understand the production of industrial gases.

CO3: Cognize the production of coal chemicals.

CO4: Know the production of pesticides and paint.

CO5: Comprehend the food and polymer technology concepts.

Mapping of course outcomes:

CO/PO	**PO**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
CO1		M	H			M	M	M				
CO2		M	M				H	L				
CO3		L	H				M	M				
CO4		L	M				L	M				
CO5		L	L			M	L	L				

UNIT 1: Introduction **9 Hours**

Introduction, classification of chemical industries, heavy and fine chemicals.

UNIT 2: Industrial Gases **9 Hours**

Introduction, manufacture and uses of carbon dioxide, nitrogen, oxygen, hydrogen, ammonia, acetylene.

UNIT 3: Coal Chemicals **9 Hours**

Various processes for obtaining coal chemicals, coal tar distillation, F-T and Bergious processes for hydrocarbon production.

UNIT 4: Pesticides and Paint Industries **9 Hours**

Pesticides: Processes for manufacturing of insecticides, fungicides and herbicides, Paint Industries: Introduction, types, manufacture and properties of paints

UNIT 5: Food and Polymer Technology **9 Hours**

Food Technology: Introduction, Food Processing Equipments, Polymer Technology: Definitions and Nomenclature, Classification According to Preparation Methods, Processing Technologies, Polymer Manufacturing Processes, Manufacture of Phenol Formaldehyde, Viscose Rayon and Nylon.

Total: 45 Hours

Textbook(s):

1. J. A. Kent, Riegel's Handbook of Industrial Chemistry, CBS press, 1997, 2010 (9^{th} Edition).

Reference(s):

1. B. K. Sharma, Industrial chemistry, Goel Publishing House, Meerut, 2006, Meerut (15^{th} Edition).

2. George T. Austin, Shreve's chemical process industries, McGraw Hill, New York, 1984 (5^{th} Edition).

213CHE1120	Materials Technology	L	T	P	C
		3	0	0	3

Prerequisite: Nil	**Course Category: Program Elective** **Course Type : Theory**

Course Objective(s):

The course content is focused on materials properties and behavior with respect to mechanical design and engineering. The course takes both a general approach and a detailed approach.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Apprehend the properties of various materials used in chemical industries.

CO2: Understand the metals, metal alloys and their uses.

CO3: Understand the non-metals and their uses.

CO4: Know the ceramic materials processing.

CO5: Understand the concepts of polymer and composite materials processing.

Mapping of course outcomes:

CO/PO	**PO**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
CO1		M	M	M								
CO2		L	M	L			H					
CO3			M		L	L						
CO4				M	L	L						
CO5				H	L	L						

UNIT 1: Introduction 9 Hours

Properties of Materials: Mechanical, Thermal, Electrical, Environmental, Manufacturing, and Economic Properties. Classification of Materials: Metals, Ceramics, Polymers, Composites, Minerals, Silicates, and Non-Silicate Minerals.

UNIT 2: Metals, Metal Alloys and Their Uses 9 Hours

Ferrous Materials: pig iron, wrought iron, grey iron etc., Non-Ferrous Metals: Aluminium, Copper, Lead, Zinc, Tin, Nickel, Rare Earth Elements, Lanthanides. Ferrous Alloys: Cast Irons, Steels, Steel Grading, Non-Ferrous Alloys: White metal, Nickel-Silver, etc., Tin

Alloys, Copper Alloys, Aluminium Alloys, Titanium Alloys, Titanium, Gold and Silver Alloys, Rare Earth Alloys.

UNIT 3: Non-metals and Their Uses **9 Hours**

Porcelain, Earthenware, Glass, Brick, Polymers, Plastics, Plant Fibres, Resins, Rubber, Composites - concrete, ceramic matrix composites, weed composites, metal matrix composites, Polymer Matrix Composites - fiberglass, carbon fibre.

UNIT 4: Working with Ceramics (and Glass) **9 Hours**

Making Pottery, Kneading and wedging, Shaping - hand building, using a potters wheel, injection moulding, jiggering, jolleying etc, Glazing - vitreous enamel, overglaze, underglaze, salt glazing, Decorating, Firing, Making Glass - hot end, cold end etc., Glass Sheet, Working with Glass - Cutting, fixing, joining, blowing

UNIT 5: Working with Polymers & Composites **9 Hours**

Synthetic Polymers, Plastic manufacturing, Joining Plastics, Plastic welding techniques, Polymer Clay, Natural Polymers -working rubber, Composites - working fiberglass, Safe Use of Materials, Sustainable Use of Materials, Recycling.

Total: 45 Hours

Textbook(s):

1. R. Balasubramaniam, Callister's Materials Science and Engineering, Wiley, 2014 (2nd Edition).

Reference(s):

1. William F. Smith, Javad Hashemi, and Ravi Prakash, Material Science and Engineering (In Si Units), McGraw Hill Education 2017 (5th Edition).

2. James F. Shackelford and William Alexander, CRC Materials Science and Engineering Handbook, CRC Press, 2000 (3rd Edition).

213CHE1121	Process Engineering Economics	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category: Program Elective** **Course Type : Theory**				

Course Objective(s):

To enable the students to understand the various concepts of economics, process development, design consideration and cost estimation in chemical industry.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Understand basics of process flow layout, diagram of chemical industries.

CO2: Know the process utilities and their application.

CO3: Understand the process instrumentation for measurements.

CO4: Know the cost estimation analysis.

CO5: Know the profit estimation analysis.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1		M	H	M								
CO2			M	M			H					
CO3			H									L
CO4				M							M	M
CO5				H							L	L

UNIT 1: Introduction 9 Hours

Chemical Engineering plant design, Overall design consideration, Plant location and site selection, plat layout, factors affecting plant location, project planning and scheduling of projects, Process selection and Development: Process creation, Process design criteria, Process flow diagram (PFD), Piping and instrumentation diagram (P&ID).

UNIT 2: Process utilities 9 Hours

process water, boiler feed water, water treatment & disposal, steam distribution, Furnaces, process pumps, compressors, vacuum pumps, valves, piping design, layout, Support for piping insulation, plant constructions.

UNIT 3: Process Instrumentation 9 Hours

measurement of temperature, pressure, fluid flow, liquid weight and weight flow rate, viscosity, pH, concentration, electrical and thermal conductivity, humidity of gases.

UNIT 4: Analysis of Cost Estimation **9 Hours**

Cash flow for industrial operations, Factors affecting investment and production costs, Capital investments, fixed capital and working capital, Estimation of capital investment, Cost indices, Estimation of total cost, Profit and cash flow, Net present value analysis, Balance sheet and Income statements, Methods for calculating Depreciation**.**

UNIT 5: Profitability Analysis **9 Hours**

Profitability standards, Costs of capital, Methods of calculating profitability, Rate of return on investment, Payback period, Discounted cash flow rate of return, Net present worth, Payout period, Alternative investments, Replacements.

Total: 45 Hours

Textbook(s):

1. Peters and Timmerhaus, Plant design and Economics for Chemical Engineers, McGraw Hill, New York, 2004 (5th Edition).

2. K. K. Ahuja, Industrial management, Khanna publishers, New Delhi, 1985.

3. H. E. Schweyer, Process Engineering Economics, McGraw Hill, New York, 1969

Reference(s):

1. F. C. Jelen and J. H. Black, Cost and Optimization Engineering, McGraw Hill, New York, 1992 (3rd Edition).

2. Robin Smith, Chemical Process Design, McGraw Hill Book Co., New York, 1995.

University Elective

214CHE1101	Corrosion Science and Engineering	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category: University Elective** **Course Type : Theory**				

Course Objective(s):

Provide fundamental understanding of aspects of electrochemistry and materials science relevant to corrosion phenomena, provide methodologies for predicting, measuring, and analyzing corrosion performance of materials and Identify practices for the prevention and remediation of corrosion.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Understand about corrosion and its forms.

CO2: Understand the requirement for protection of boiler against corrosion.

CO3: Understand the various corrosion test and its ASTM standards.

CO4: Understand Polarization and Effect of oxidizing agents on corrosion.

CO5: Understand the Corrosion prevention methods and its applications.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H		M									
CO2			H									
CO3				H								
CO4					L							
CO5			H									

UNIT 1: Corrosion **9 Hours**

Corrosion - Definition, classification, forms of corrosion, expressions for corrosion rate, emf and galvanic series, merits and demerits, Pourbaix diagram for iron, magnesium and aluminium - Forms of corrosion, Uniform, pitting, intergranular, stress corrosion - Corrosion fatigue - Dezincification - Erosion corrosion - Crevice corrosion - Cause and remedial measures, Pilling Bedworth ratio, High temperature oxidation).

UNIT 2: Boilers **9 Hours**

Boiler water corrosion by carbon dioxide and unstabl7e5 salts - Corrosion prevention methods by treatment cooling water, specification, types of scales and causes, use of anti scalant - Water treatments – Maintenance of boilers - Protection of boilers during off loading, high temperature, corrosion, turbine corrosion – Corrosion inhibitors, principles and practice, inhibitors for acidic neutral and other media - Corrosion failure – Inspection and analysis of corrosion damage.

UNIT 3: Corrosion Testing **9 Hours**

Purpose of corrosion testing, classification, susceptibility tests for intergranular corrosion, stress corrosion test, salt spray test, humidity and porosity tests, accelerated weathering tests – ASTM standards for corrosion testing.

UNIT 4: Polarization **9 Hours**

Polarization - Exchange current density, Activation polarization, Tafel Equation, Passivating metals and non-passivating metals, Effect of oxidizing agents**.**

UNIT 5: Electroless Plating and Anodizing **9 Hours**

Electroless plating and Anodizing - Cathodic protection, metallic, organic and inorganic coatings, corrosion inhibitors - Special surfacing processes - CVD and PVD processes, sputter coating - Laser and ion implantation, arc spray, plasma spray, flame spray, HVOF.

Total: 45 Hours

Textbook(s):

1. Fontana and Greene, Corrosion Engineering, McGraw Hill Book Co., New York, 2006.

2. Raj Narayan, An Introduction to Metallic Corrosion and its prevention, Oxford and IBH, New Delhi, 2002.

Reference(s):

1. K. G. Budinski. Surface Engineering for Wear Resistance, Prentice Hall Inc., - Englewood Cliff, New Jersey, USA, 2005.

2. H. H. Uhlig, Corrosion and Corrosion Control, John Wiley and Sons, New York, 2001.

214CHE1102	Separation Technique	L	T	P	C
		3	0	0	3

Prerequisite: Nil

Course Category: University Elective

Course Type : Theory

Course Objective(s):

The main objective of this course is to familiarize students with the fundamental principles of separation processes used in analytical chemistry such as various extraction techniques, gas and liquid chromatography, size and ion chromatography and electrophoresis.

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Course Outcomes(s):

At the end of the course the students would be able to

CO1: Understand the equilibrium state.

CO2: Understand the Prospects of ionic separation.

CO3: Understand the various separation techniques and its standards.

CO4: Understand the chromatographic techniques and its applications.

CO5: Understand the need of various separation techniques.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1		H										
CO2												
CO3			M	M								
CO4				M		L						
CO5				H								

UNIT 1: Thermal Separation **9 Hours**

Thermal Diffusion: Basic Rate Law, phenomenological Theories of Thermal Diffusion for gas and liquid mixtures, Equipments design and Applications. Zone Melting: Equilibrium diagrams, Controlling factors, Apparatus and Applications.

UNIT 2: Adsorption Techniques **9 Hours**

Types and choice of adsorbents, Normal Adsorption techniques, chromatographic techniques, types and Retention theory mechanism Equipment and commercial processes, Recent advances and economics, Molecular Sieves.

UNIT 3: Membrane Separation Processes **9 Hours**

Types and choice of membranes, their merits, commercial, pilot plant and laboratory membrane permeators, Dialysis, Reverse Osmosis, Ultra filtration, Concentration Polarization in Membrane and Economics of Membrane operations.

UNIT 4: Ionic Separation **9 Hours**

Controlling factors, Applications, Equipments for Electrophoresis, Dielectrophoresis, Electro Dialysis and Ion - Exchange, Commercial processes.

UNIT 5: Other Techniques **9 Hours**

Adductive crystallization: Molecular addition compounds, Clathrate compounds and adducts, Equipments, Applications, Economics and Commercial processes. Foam Separation: Surface Adsorption, Nature of foams, Apparatus, Applications, and Controlling factors.

Total: 45 Hours

Textbook(s):

1. H. M. Schoen, New Chemical Engineering Separation Techniques, Inter Science Publications, New York, 2002.

2. C. Loeband, and R. E. Lacey, industrial Processing with Membranes, Wiley Inter Science, 2002.

3. B. Sivasankar, Bioseparations: Principles and Techniques, Prentice Hall of India Pvt. Ltd., New Delhi - 2005.

Reference(s):

1. R. H. Perry and D. W. Green, Perry's Chemical Engineers Hand book, McGraw Hill, New York, 2007(8th Edition).

2. J. M. Coulson and J. F. Richardson, Chemical Engineering Vol. II, Butterworth – Heinemann, London – 2004 (5th Edition).

214CHE1103	Fertilizer Technology	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** University Elective **Course Type:** Theory				

Course Objective(s):

Indian economy is dominated by agriculture sector. Synthetic fertilizers are must for producing good crops. Hence it is needed to provide comprehensive and balanced understanding of essential link between chemistry and the synthetic fertilizer industry. It is therefore vital for chemical engineers to understand for each fertilizer product, its flow diagram for Industry production.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Understand the global outlook of fertilizer resources.

CO2: Elaborate the production processes of nitrogenous fertilizers.

CO3: Understand the about phosphate fertilizer production.

CO4: Understand the production processes of NPK fertilizers.

CO5: Understand about the mixed fertilizers.

Mapping of course outcomes:

CO/PO	PO											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
CO1		M										
CO2				H								
CO3			L									
CO4				H								
CO5							M					

UNIT 1: Global Outlook of Fertilizer Resources **9 Hours**

Role of organic manures and Chemical Fertilizers - Types of Chemical fertilizers, growth of fertilizer industry in India, their location, energy consumption in various fertilizer processes - materials of various fertilizer processes, materials consumption in fertilizer industry.

UNIT 2: Nitrogenous Fertilizers **9 Hours**

Feed stock for production of Ammonia, Natural gas, associated gas, Coke oven gas, Ammonium Sulphate, Ammonium Nitrate, Urea, Calcium Ammonia Nitrate, Ammonium chlorides - Methods of Production, characteristics and specification - Storage and handling.

UNIT 3: Phosphate Fertilizer **9 Hours**

Raw materials for the manufacture of Phosphate fertilizer - Phosphate Rock, Sulphur, Pyrites etc., - Processes for the production of Sulfuric and Phosphoric acid - Phosphate fertilizers, ground rock phosphate, bone meal, methods of production, characteristics and specifications for single super phosphate, triple super phosphate.

UNIT 4: NPK Fertilizers **9 Hours**

NPK Fertilizers - Methods of production, Characteristics and specifications for complex fertilizers, methods of production of Ammonia phosphate, Sulphate, Di-ammonium phosphate and Nitro phosphates – NPK Fertilizers - Urea, Ammonium Phosphate, Monoammonium Phosphate and various grades of NPK fertilizers produced in the country.

UNIT 5: Mixed Fertilizers **9 Hours**

Mixed fertilizers - Granulated mixtures - Bio fertilizers - Secondary and Micro Nutrients, Fluid Fertilizers - Controlled release fertilizers - Pollution from fertilizer industry - Solid, liquid and gaseous pollution standards.

Total: 45 Hours

Textbook(s):

1. A. V. Slack. Chemistry and Technology of Fertilizers – Inter Science, New York, 2005.

2. M. E. Pozin, Fertilizer Manufacture, MIR Publishers, Moscow, 2006.

Reference(s):

1. L. J. Carpentire, New Developments in Phosphate Fertilizer Technology, Elsevier, New Delhi, 2001.

2. Strelzoff, Technology and Manufacture of Ammonia, John Wiley and Sons, New York, 2004 (8^{th} Edition).

214CHE1104	Membrane Science and Technology	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** University Elective **Course Type:** Theory				

Course Objective(s):

To gain knowledge on basic principles of membrane process; To design membrane modules for Reverse osmosis, Ultracentrifugation and gas separation process; To understand the various applications of membranes in medical field.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Elaborate the types of membrane, its Structure and theory.

CO2: Explain different types of membranes and its modules.

CO3: Detail various flow processes using Membranes.

CO4: Analyze membrane filtration, applications and its design.

CO5: Apply Membranes in medical applications.

Mapping of course outcomes:

CO/PO	**PO**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
CO1			M			H						
CO2			M	M								
CO3				M		H						
CO4			H	M	M							
CO5			H		L		L					

UNIT 1: Membranes **6 Hours**

Membranes - Types, membrane process, membrane transport theory, solution diffusion model - Structure, permeability relationships, pore, flow membranes.

UNIT 2: Liquid Membranes **6 Hours**

Membranes and modules, isotropic membranes, anisotropic membranes, metal membranes and ceramic membranes, liquid membranes, hollow fibre membranes, membrane modules.

UNIT 3: Concentration polarization **10 Hours**

Concentration polarization - Liquid separation process, gas separation process, cross flow, co-flow and counter flow - Reverse osmosis, theoretical background, membrane selectivity, module, fouling.

UNIT 4: Ultracentrifugation **12 Hours**

Ultracentrifugation membranes - Characterization of ultrafiltration membranes - Modules, System design - Micro filtration, background and applications - Pervaporation, membrane materials, process design - Ion exchange membrane, chemistry of ion exchange membranes, transport in electro dialysis membrane, system design.

UNIT 5: Medical Applications **11 Hours**

Medical Applications - Haemodialysis - Blood oxygenators, control drug delivery, membrane processes dialysis - Donan dialysis and diffusion dialysis - Charge mosaic membranes and piezo dialysis, membrane contractors and membrane distillation, membrane reactors.

Total: 45 Hours

Textbook(s):

1. R. W. Baker, Membrane Technology and Applications, Wiley-Inter Science, Singapore, 2012 (3^{rd} Edition).

2. H. Strathmann, Ion Exchange Membrane Separation Processes Vol. 9, Elsevier Science, 2004 (1^{st} Edition).

Reference(s):

1. W. R. Vieth, Membrane Systems Analysis and Design Applications in Biotechnology, Biomedicine and Polymer Science, Wiley-Inter Science, Singapore, 1994.

2. S. F. Timashev, and T. J. Kemp, Physical Chemistry of Membrane Process, Prentice Hall, New Jersey, 1991.

3. Marcel Mulder, Basic Principles of Membrane Technology, Kluwer Academic Publishers, New York - 1996(2ndEdition).

214CHE1105	Process Industrial safety	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** University Elective **Course Type:** Theory				

Course Objective(s):

To familiarize basics of Industrial safety principles; To know the various aspects of health hazards and Industrial accidents in Chemical Industries.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Identify, Explain and Handle Different safety principles

CO2: Identify Different Hazards and their Fire protection agencies

CO3: Analyze various health hazards

CO4: Identify Safety aspects of reactive chemicals

CO5: Identify Hazards Safety in operations and processes.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	M		H				L					
CO2			H									
CO3			H									
CO4			H									
CO5			H	L								

UNIT 1: Introduction **9 Hours**

Introduction - Industrial safety principles, Site selection and plant layout, Legal Aspects, design for ventilation - Emergency response systems for hazardous goods basic rules and requirements which govern the chemical industries.

UNIT 2: Hazards **9 Hours**

Chemical hazards - Classification, Hazards due to fire, explosion and radiation - Reduction of process hazards by plant condition monitoring - Materials Safety Data sheets and National Fire protection agency's classifications.

UNIT 3: Diseases **9 Hours**

Dangerous occupational diseases, poisoning, dust effect – Biomedical and engineering response to health hazards.

UNIT 4: Control of Hazards **9 Hours**

Control of Hazards Engineering control of plants instrumentation - Colour codes for pipe lines - Safety aspects of reactive chemicals.

UNIT 5: Operation and Process Hazards **9 Hours**

Operation and Process Hazards Safety in operations and processes - Runaway reactions - unstable products.

Total: 45 Hours

Textbook(s):

1. Daniel A. Crowl and Joshef F. Louvar, Chemical Process Safety: Fundamentals with application, Prentice Hall, 2011(3rd Edition).

2. John Barton, and Richard Rogers, Chemical Reaction Hazards, John Wiley and Sons, Singapore, 1997(2nd Edition).

Reference(s):

1. T. Yoshida, Safety of Reactive Chemicals - Vol. I, Elsevier, New Delhi, 1987.

2. Ralph William King, Industrial Safety Handbook, McGraw Hill, New York, 1968 (2nd Edition).

3. H. H. Fawcett, and W. S. Wood, Safety and Accident Prevention in Chemical Operation, Wiley-Inter Science, Singapore, 1982(2nd Edition).

214CHE1106	Fuel and Combustion Engineering	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** University Elective **Course Type:** Theory				

Course Objective(s):

To understand the basic principles and calculations involved in combustion process; To know the different aspects of combustion appliances and processing techniques in detail.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: To analyze the fuel process

CO2: To apply the thermodynamic combustion systems

CO3: Ability to understand the furnace process in industries

CO4: To understand the purpose of flame propagation

CO5: Ability to require the processing of burner.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1				H	M							
CO2	H		M				L					
CO3		L					H	M				
CO4					L		M	H				
CO5			H		M							

UNIT 1: Introduction **9 Hours**

Fuels & Fuel Analysis-Combustion Stoichiometry, theoretical & actual combustion processes – Air fuel ratio.

UNIT 2: Combustion **9 Hours**

Combustion Thermodynamics- calculation of heat of formation & heat of combustion – First law analysis of reacting systems.

UNIT 3: Furnaces **9 Hours**

Heat Treatment Furnaces- Industrial furnaces – process furnaces – Kilns – Batch & continuous furnaces.

UNIT 4: Flame **9 Hours**

Flame, Flame Structure, Ignition and Igniters – flame propagation – deflagration – detonations - flame front – Ignition – self & forced ignition – Ignition temperature.

UNIT 5: Burners **9 Hours**

Combustion Appliances- Gas burners- Functional requirement of burners – Gas burner Classification –Stoker firing –pulverized system of firing.

Total: 45 Hours

Textbook(s):

1. S. P. Sharma and Chander Mohan, Fuels and Combustion, Tata McGraw Hill Publishing Co.

Ltd., 1984

2. Samir Sarkar, Fuels and Combustion, Universities press, 2010 (3rd Edition).

Reference(s):

1. A. G. Blokh, Heat Transmission in Steam Boiler furnaces, CRC Press, 1987 (1st Edition).

2. O. P. Gupta, Elements of Fuels, Furnaces & Refractories, Khanna Publishers, 1989 (6th Edition).

3. Roger A. Strehlow, Combustion Fundamentals, McGraw Hill, New York, 1984.

4. A. K. Shaha, Combustion Engineering and Fuel Technology, Oxford and IBH, 1974.

5. Kenneth K. Kou, Principles of Combustion, John Wiley & Sons, 2005(2nd Edition).

214CHE1107	Pulp and Paper Technology	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** University Elective **Course Type:** Theory				

Course Objective(s):

To introduce the working principle of various machines used for the production of paper to understand the paper manufacturing process in detail.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Apply different machines in Paper Industry

CO2: Understand the function and maintenance of Fourdrinier

CO3: Apply driers in Paper and Pulp Industry

CO4: Describe about special paper machines

CO5: Detail various processes of paper finishing.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1			H	L								
CO2			H	M	M							
CO3		H	L									
CO4				H								
CO5						H						

UNIT 1: Basics of Pulp and Paper Technology **9 Hours**

Describe the consumption pattern of different types of paper, describe cellulose raw material, identify problems and scope in India.

UNIT 2: Pulp **9 Hours**

Explain various raw materials. Differentiate the various pulping processes; describe the Kraft pulping process with flow diagram. Compare various types of pulps, Explain chemical recovery process.

UNIT 3: Paper **9 Hours**

Differentiate the features f various raw materials used in paper manufacture, describe the Wet process for paper Manufacture with flow diagram Describe Fourdrinier machine, and describe the economics in paper industry.

UNIT 4: Cellulose and Lignin Chemicals **9 Hours**

Describe the properties of cellulose, prepare chemical cellulose, Describe the characteristics of Lignin chemicals, Selection of cellulose and lignin chemicals.

UNIT 5: Waste Disposal Techniques **9 Hours**

Analyze pollution potentials of Indian pulp and paper industry, apply bio-technical approach for pollution, Apply Lignin waste treatment.

Total: 45 Hours

Textbook(s):

1. George D. Bearce, Manufacture of Pulp and Paper – Vol. V, McGraw Hill, New York, 2008.

2. R. W. J. MacKinney, Technology of Paper Recycling, Springer Publishers, London, 1994.

Reference(s):

1. Asten Sabit Adanur, Paper Machine Clothing: Key to the Paper Making Process, CRC Press,

New York, 1997.

2. Allison Stark Draper, Paper and Pulp Industry, Rosen Publishing Group, 2001.

214CHE1108	Treatment of Industrial Effluents	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** University Elective **Course Type:** Theory				

Course Objective(s):

To acquire in depth knowledge of waste water treatment and characterization methods; To introduce the hazardous nature of effluent and water treatments methods followed in various industries.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Describe the nature and composition of industrial pollutants, their origin and their impact on the environment.

CO2: Explain the principles of various processes available for wastewater treatment

CO3: Choose methods for waste minimization and water conservation

CO4: List the problems associated with the operation of industrial wastewater treatment facilities and provide an explanation of the causes and possible solutions

CO5: Determine the toxicity levels of industrial effluents.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	M						L					
CO2			M									
CO3			H	L								
CO4				M	H							
CO5												

UNIT 1: Characterization of wastewaters **9 Hours**

Quality of various industrial effluents, permissible limits, Fundamentals of wastewater treatment technologies, water treatment equipments.

UNIT 2: Biological treatment **9 Hours**

Biological fluidized bed reactors for treatment of sewage and industrial effluents - anaerobic digestion and anaerobic contact process - denitrification - fluidized bed anaerobic reactors - anaerobic down flow stationary fixed film reactors.

UNIT 3: Biological wastewater treatment **9 Hours**

Completely mixed aerated lagoons, oxidation ditches and waste stabilization ponds - activated sludge - microbial community in activated sludge - aerobic digestion, trickling filters - rotating biological contactors - nitrification.

UNIT 4: Application of Biological Treatment in Industries **9 Hours**

Waste water treatment and disposal of tannery-dye factory-sugar industry-pulp and paper industry -viscose industry - agro chemical industries- fertilizer industries - petro chemical industry and pharmaceutical industries.

UNIT 5: Treatment of gaseous pollutants **9 Hours**

Ambient air sampling, analysis methods and measuring devices; air pollution standards, air pollution control equipments; Case studies of gaseous effluent treatment in typical industries: steel plants, power plants etc.

Total: 45 Hours

Textbook(s):

1. N. W. Jern, Industrial waste water Treatment, Imperial College Press, 2006.

Reference(s):

1. R. S. Ramalho, Introduction to Waste Water Treatment Process, Academic press Imprint, New York, 2013 (2nd Edition).

2. S. D. Lin and C. C. Lee, Water and Waste Water Calculation Manual, McGraw Hill, 2014 (3rd Edition).

214CHE1109	Coal Processing Technology	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** University Elective **Course Type:** Theory				

Course Objective(s):

To introduce the importance of coal and its processing method; To understand the principle of coal refining and utilization process in detail.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: To Understand the role& importance of Coal

CO2: Able to understand the production methods of coal & also the concepts of modeling

CO3: To provide the application of coal in power generation & various kinetics of solvent extraction.

CO4: To understand the different refining process

CO5: To Analyze the impacts of various process on Environment.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	M	H	M									
CO2	H	H	M	M								
CO3	H	M	H	L	L							
CO4	M	M	H	H								
CO5			M		M		L					

UNIT 1: Role of Coal **9 Hours**

Role of coal in the overall energy situation, Recent advances in coal preparation methods including fine coal treatment.

UNIT 2: Simulation and Modeling **9 Hours**

Simulation and modelling of coal beneficiation circuits, Thermodynamics and kinetics of coal gasification reactions, Fluidized bed coal gasification processes.

UNIT 3: Power generation **9 Hours**

Combined cycle power generation, Coal liquefaction, Various methods, kinetics of solvent extraction, Catalytic hydrogenation and other liquefaction processes.

UNIT 4: Refining **9 Hours**

Absorptive and adsorptive purification, sulphuric acid purification, Concept of coal refinery and coal plex.

UNIT 5: Environmental impact **9 Hours**

Analysis of coal utilization methods such as carbonization, gasification, etc.

Total: 45 Hours

Textbook(s):

1. H. L. Lowry, Chemistry of Coal Utilization - Vol. I & Vol. II, John Wiley and Sons, New York, 1963.

Reference(s):

1. E. C. Mangold, Coal Liquefaction and Gasification Technologies, Ann Arbor Science Publishers, 1982.

2. Joseph H. Wilson, and Philip J Wells, Coal, Coke, and Coal Chemicals (Chemical Engineering Series), McGraw Hill, 1950.

214CHE1110	Batteries And Fuel Cells	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** University Elective **Course Type:** Theory				

Course Objective(s):

To gain basic knowledge on batteries; introduce alternate sources for fuels and identify their applications in various fields.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Understand the importance of cell and batteries.

CO2: Explain the characteristics of electromagnetic reactions.

CO3: Explain the concept of batteries and their applications.

CO4: Evaluate the fundamental principles of fuel cells.

CO5: Describe industrial oriented application of fuel cells.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1					H				L			M
CO2							L					
CO3	L		M							M		
CO4					H							M
CO5		H										

UNIT 1: Introduction 9 Hours

Concepts – Components of cells and batteries, Classification of cells and batteries, Operation of a cell, Specifications – Free energy, theoretical cell voltage, specific capacity, specific energy, energy density, memory effect, cycle life, shelf life, state of charge (SOC) and depth of discharge (DOD), internal resistance and coulombic efficiency.

UNIT 2: Characteristics of electrochemical reaction 9 Hours

Electrochemical principles and reactions – electrical double layer, discharge characteristics of cell and polarization, Electrode processes and Tafel polarization, thermodynamic background and Nernst equation.

UNIT 3: Batteries **9 Hours**

Primary and secondary batteries – Zn/C, Zn/air, alkaline cells, lithium primary batteries, lead-acid, Ni/Cd, Ni/MH and Lithium secondary batteries (Components, Chemistry and Performance characteristics). Applications of storage batteries.

UNIT 4: Fuel cells **9 Hours**

Fuel cell fundamentals, The alkaline fuel cell, Acidic fuel cells, SOFC (components, chemistry and challenges) - Emerging areas in Fuel cells.

UNIT 5: Applications of fuel cells **9 Hours**

Fuel cell outlook, Applications of fuel cells – Industrial and commercial.

Total: 45 Hours

Textbook(s):

1. David Linden and Thomas. B. Reddy, Hand Book of Batteries and Fuel cells, McGraw Hill

Book Company, New York, 2005 (3rd Edition).

2. John O'M Bockris, Amulya K. N. Reddy and Maria Gamboa Aldeco, Modern Electrochemistry, Kluwer Academic Publishers, New York, 2006 (2nd Edition).

Reference(s):

1. Xianguo Li, Principles of Fuel Cells, Taylor & Francis, 2006.

2. B. Viswanathan, and Alice M. Scibioh, Fuel Cells, Principles and Applications - Universities

Press, 2006 (3rd Edition).

214CHE1111	Drugs and Pharmaceuticals Technology	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** University Elective **Course Type:** Theory				

Course Objective(s):

To introduce basic concepts regarding drug engineering which serves as the backbone of medical and pharmaceutical industry.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Know the basics of drugs and pharmaceutical technology

CO2: Understand the chemical conversion processes and their equipments.

CO3: Understand basic unit operations

CO4: Understand the basic idea for design of processes and equipments used for drug manufacturing.

CO5: Study various pharmaceutical products.

Mapping of course outcomes:

CO/PO	PO											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
CO1		H			M							
CO2					M		L					
CO3	H		L									
CO4					M				H			
CO5		H										

UNIT 1: Introduction **9 Hours**

Development of Drugs and Pharmaceutical Industry, Organic Therapeutic agents, Uses and Economics.

UNIT 2: Drugs metabolism and pharmacokinetics **9 Hours**

Drugs metabolism; Physio - Chemical principles, Radio Activity, Pharma Kinetics, Actions of drugs on human bodies.

UNIT 3: Important unit processes and their applications 9 Hours

Chemical conversion processes: Alkylation, Carboxylation, Condensation and Cyclisation, Dehydration, Esterification (Alcoholysis), Halogenation, Oxidation, Sulphonation, Complex chemical Conversion, Fermentation.

UNIT 4: Pharmaceuticals, microbiological and animal products 9 Hours

Vitamins, Cold remedies, Laxatives, Analgesics, Non-steroidal contraceptives, External Antiseptics, Antacids and Others, Antibiotics, Biologicals, Hormones, Vitamins, and Preservation, Pharmaceutical Analysis. Analytical methods and test for various drugs and pharmaceuticals.

UNIT 5: Manufacturing principles 9 Hours

Compressed tables, Wet granulation, Dry granulation or Slugging, Direct compression, Tablet Presses, Formulation, Coating, Pills, Capsules, Sustained action dosage forms, Parental solutions, Oral liquids, Injectable, Ointments, Standard of hygiene and good manufacturing practice as per Drugs and Cosmetics Act as amended update, Packing, Packing techniques, Quality control.

Total: 45 Hours

Textbook(s):

1. O. D. Tyagi, AND M. A. Yadav, Text Book of Synthetic Drugs, Anmol Publications, New Delhi, 2011 (3rd Edition).

2. G. R. Chatwal Synthetic Drugs, Himalaya Publishing House, Delhi, 2009 (3rd Edition).

Reference(s):

1. E. A. Rawlins, Bentley’s Text Book of Pharmaceutics, Elsevier/BSP Books Pvt. Ltd., 2010.

2. Adeboye Adejare, Remington: The Science and Practice of Pharmacy, Elsevier, 2021 (21st Edition).

214CHE1112	Polymer Science And Technology	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** University Elective **Course Type:** Theory				

Course Objective(s):

To introduce basic concepts regarding drug engineering which serves as the backbone of medical and pharmaceutical industry.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Ability to identify the common commercial polymers by their names, properties and syntheses

CO2: Understand the properties and applications of polymers processing methodology

CO3: Apply the mechanisms of polymer degradation

CO4: Analyze the polymer additives and their role in the control of desired properties

CO5: Perform various polymer fabrication methods of extrusion, moulding and conversion of fibres to fabrics.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	M											
CO2			H									
CO3		M										
CO4			H									
CO5						M						

UNIT 1: Introduction **9 Hours**

Classification and characterization of polymers - Thermal analysis, Morphological characterization, Physical testing.

UNIT 2: Properties of Polymer **9 Hours**

Morphology and order in crystalline polymers - Rheology and mechanical properties of polymer structure and physical properties.

UNIT 3: Polymerization **9 Hours**

Polymerization - Step reaction polymerization, Chain reaction polymerization, free radical, anionic, cationic, coordination - Copolymers and Copolymerization - Polymerization conditions.

UNIT 4: Plastics and Resins **9 Hours**

Hydrocarbon plastics and elastomers - Other carbon chain polymers – Hetero chain thermoplastics - Thermosetting Resins - Types of deformation.

UNIT 5: Technologies **9 Hours**

Plastic technology - Fiber technology- Elastomer technology.

Total: 45 Hours

Textbook(s):

1. F. W. Billmeyer, Text book of Polymer Science, Wiley Publishers, Singapore, 1994 (3rd Edition).

2. A. Rudin, Elements of Polymer Science and Engineering an Introductory Text and Reference for Engineers, Elsevier, New Delhi, 1998 (2nd Edition).

Reference(s):

1. Anil Kumar, and R. K. Gupta, Fundamentals of Polymers, McGraw Hill, New York, 1998.

2. N. P. Cheremisinoff, Polymer Mixing and Extrusion Technology, CRC Press, 2017.

3. F. Rodriguez, Principles of polymer systems, Taylor and Francis, Washington, 1996.

214CHE1113	Pharmaceutical Engineering	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** University Elective **Course Type:** Theory				

Course Objective(s):

To introduce basic concepts regarding drug engineering which serves as the backbone of medical and pharmaceutical industry.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Apply the principles of pharmacokinetics and pharmacodynamics

CO 2: Analyze the mechanisms of chemical conversion processes

CO 3: Apply the manufacturing processes of various pharmaceutical products

CO 4: Describe various antipyretic and anti-inflammatory agents

CO 5: Apply analytical techniques of pharmaceutical products and their quality control.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H		M							L		
CO2			H						L			
CO3			H			L		M				
CO4				H								
CO5					H							

UNIT 1: Development of Drugs and Pharmaceutical Industry 9 Hours

Development of drugs and pharmaceutical industry - Organic therapeutic agents uses and Economics - Drug Metabolism and Pharmacokinetics - Drug Metabolism Physio Chemical principle, Radioactivity, Pharma kinetic reaction of Drugs on Human bodies.

UNIT 2: Chemical Conversion Processes 9 Hours

Chemical conversion processes - Alkylation, carboxylation, condensation and cyclisation, dehydration, esterification, halogenations, oxidation, sulfonation, complex chemical conversions, fermentation.

UNIT 3: Granulation **9 Hours**

Compressed Tablets - Wet granulation - Dry granulation or slugging - Direct compression Tablet Presses, Formulation, Coating Pills, Capsules, Sustained dosage Forms, Parental Solution - Oral liquids - Injections External preparations - Ointments - Standard of Hygiene and Good Manufacturing practice as per Drugs and Cosmetics Act as amended update.

UNIT 4: Antipyretic and Anti Inflammatory **9 Hours**

Based on Antipyretic and anti-inflammatory, respiratory, cardio intestinal and liver, hormones, stimulants, histamine and anti-histamine, vitamins and other nutrients, sedatives, analgesics Aerosols: mode of operations, propellants- container-, valves- actuato89rs and buttons- dip tubes, packing, application and testing Liposome- fundamentals of manufacturing, evaluation, advantages & limitations, application. Noisome & their fundamentals- Iontophoresis & sonophoresis - fundamentals- evaluation & applications.

UNIT 5: Antibiotics **9 Hours**

Antibiotics - Anti-infective, biological, hormones, vitamins and preservation, pharmaceutical analysis, Analytical methods and tests for various drugs and pharmaceuticals, packing techniques, quality control.

Total: 45 Hours

Textbook(s):

1. E. A. Rawlins, Bentley's Text Book of Pharmaceutics, Elsevier/BSP Books Pvt. Ltd., 2010.

2. Adeboye Adejare, Remington: The Science and Practice of Pharmacy, Elsevier, 2021 (21st Edition).

Reference(s):

1. I. R. Berry and R. A. Nash, Pharmaceutical Process Validation, Second Edition: 57 (Drugs and the Pharmaceutical Sciences), CRC Press,1993 (1st Edition).

2. A. J. Hickey, and D. Ganderton, Pharmaceutical Process Engineering: 195 (Drugs and the Pharmaceutical Sciences), CRC Press, 2009 (2nd Edition).

3. S. G. Turner, Pharmaceutical Engineering Change Control, 2019 (2nd Edition).

214CHE1114	Disaster Management in Chemical Industries	L	T	P	C
		3	0	0	3

Prerequisite: Nil

Course Category: University Elective

Course Type: Theory

Course Objective(s):

This course aims to deliver the knowledge and skills on multi-dimensional aspects of chemical disaster risk management and emergency incident-response. It also addresses the paradigm shift to prevention and mitigation, effective preparedness for emergency response, disaster relief and rehabilitation including delivery of compensations, liabilities, issues related to litigations.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: To understand the basic concept in Disaster Management

CO 2: Discuss the consequences and control factors of Disaster

CO 3: To undertake Mitigation & Risk Reduction steps

CO 4: To understand the institutional and legal framework for India

CO5: To induce knowledge to create appropriate planning, preparation and response for emergency treatment in disaster situation.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1							H	M		L		
CO2		M	H								L	
CO3				M		H						
CO4				L			H	M				
CO5	H			M								

UNIT 1: Understanding Disasters **9 Hours**

Disaster and Development, and disaster management Chemical hazards: Classification of chemical hazards, Chemical as cause of occupational diseases – dust, fumes, gases and vapours; Hazard analysis and health management; Engineering control of chemical plant hazards – Plant layout, ventilation and lighting, Pressure vessels, Storage, Handling, Transportation, Electrical systems, Instrumentation; Emergency planning, Personal protective devices, Maintenance procedure.

UNIT 2: Control of Disasters **9 Hours**

Geological Disasters (earthquakes, landslides, tsunami, mining); Hydro-Meteorological Disasters (floods, cyclone, lightning, thunder-storms, hail storms, avalanches, droughts, cold and heat waves) Biological Disasters (epidemics, pest attacks, forest fire); Technological Disasters (chemical, industrial, radiological, nuclear) and Man- made Disasters (building collapse, rural and urban fire, road and rail accidents, nuclear, radiological, chemicals and biological disasters) Global Disaster Trends – Emerging Risks of Disasters – Climate Change and Urban Disasters.

UNIT 3: Disaster Management Cycle and Framework **9 Hours**

Disaster Management Cycle – Paradigm Shift in Disaster Management Pre-Disaster – Risk Assessment and Analysis, Risk Mapping, zonation and Micro-zonation, Prevention and Mitigation of Disasters, Early Warning System; Preparedness, Capacity Development; Awareness During Disaster – Evacuation – Disaster Communication – Search and Rescue – Emergency Operation Centre – Incident Command System – Relief and Rehabilitation – Post-disaster – Damage and Needs Assessment, Restoration of Critical Infrastructure – Early Recovery – Reconstruction and Redevelopment; IDNDR, Yokohama Strategy, Hyogo Framework of Action.

UNIT 4: Disaster Management in India **9 Hours**

Disaster Profile of India – Mega Disasters of India and Lessons Learnt Disaster Management Act 2005 – Institutional and Financial Mechanism National Policy on Disaster Management, National Guidelines and Plans on Disaster Management; Role of Government (local, state and national), Non-Government and Inter-Governmental Agencies.

UNIT 5: Applications of Science And Technology For Disaster Management **9 Hours**

Geo-informatics in Disaster Management (RS, GIS, GPS and RS) Disaster Communication System (Early Warning and Its Dissemination) Land Use Planning and Development Regulations Disaster Safe Designs and Constructions Structural and Non-Structural Mitigation of Disasters S&T Institutions for Disaster Management in India.

Total: 45 Hours

Textbook(s):

1. H. H. Tawcatt and W. S. Wood, Safety and Accident Prevention in Chemical Operations, Wiley, 2008 (2nd Edition).

Reference(s):

1. R. V. Betrabet and T. P. S. Rajan in CHEMTECH-I, Safety in Chemical Industry, Chemical Engineering Development Centre, IIT Madras, 2010.

2. Disaster Management Guidelines. GOI-UNDP Disaster Risk Reduction Programme, 2009-2012.

214CHE1115	Photonics and Optoelectronic Devices	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** University Elective **Course Type:** Theory				

Course Objective(s):

This course introduces the students to the field of Semiconductor Optoelectronics, which deals with the physics and technology of semiconductor optoelectronic devices such as light emitting diodes, laser diodes and photodiodes, which are becoming important components in consumer optoelectronics, IT and communication devices, and in industrial instrumentation.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Know the fundamentals of fibre based optical devices

CO-2: Understand the basic of integrated optical devices

CO-3: Learn about the optoelectronic devices

CO-4: Understand the nanostructured materials

CO-5: Understand the quantum devices with applications.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1							H	M		L		
CO2		M	H								L	
CO3				M		H						
CO4				L			H	M				
CO5	H			M								

UNIT 1: Optical Fibre based Devices **9 Hours**

Fused single mode fibre directional coupler, polished single mode fibre directional coupler; Fibre polarizer; Polarization splitters based on fibre; Single mode fibre filter; Polarization controller; Wavelength multiplexer and De-multiplexer; Optical fibre switches and intensity modulators; Optical fibre phase modulator; Optical fibre frequency modulator; Optical fibre amplifiers.

UNIT 2: Integrated Optic based Devices **9 Hours**

Optical directional coupler: directional coupler wavelength filter, polarization splitting directional coupler; Polarizers:

Minors

217CHE2101	Chemical Process Calculations	L	T	P	C
		3	0	0	4
Prerequisite: Nil	**Course Category:** Minors **Course Type:** Theory				

Course Objective(s):

To develop systematic problem solving skills, to learn what material balance and energy balance are, how to formulate, apply and solve them and to learn how to deal with the complex process problems.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Describe the fundamentals of stoichiometry

CO2: Apply material balances on unit operations and processes

CO3: Evaluate humidity with/without the use of psychometric chart

CO4: Apply Energy balance to unit operations and processes

CO5: Apply Energy and Material balance to industrial processes

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H	M										
CO2	H	H										
CO3		H										
CO4	H	H										
CO5	H	M						L	L	L		

UNIT 1: Introduction **9 Hours**

Units and dimensions and conversions - Mass and volume relations -Stoichiometric and Composition relations, Degree of completion - Ideal gas law, Dalton's Law, Amagat’s Law, Average molecular weight of gaseous mixtures - Vapor Pressure, Effect of temperature on vapor pressure, Vapor pressure plot- Clasius-Clapeyron equation, Cox Chart, Duhring’s Plot Raoult's Law.

UNIT 2: Material Balance **9 Hours**

Material balance without chemical reaction Drying, Mixing, Crystallization, Extraction, Absorption, Distillation and evaporation, Analysis of system with bypass, Recycle and purging, Psychometric, Humidification and dehumidification. Steady state and unsteady state material balances Material balances for systems with and without chemical reactions – Material balance applied to different unit operations- Analysis of systems with by-pass, recycle, and aid of computers in solving material balance problems.

UNIT 3: Humidity and saturation **9 Hours**

Material balance with chemical reaction Principles of Stoichiometry, Concept of limiting, Excess reactants and Inert, Fractional and Percentage conversion, Fractional yield and Percentage yield, Selectivity, related problems. Relative and Percent saturation - Dew point - Dry and Wet bulb temperatures - Use of humidity charts for engineering calculations

UNIT 4: Energy Balance **9 Hours**

Heat capacity of gases, liquids and solutions - Heat of fusion and vaporization - Steady state energy balance for systems with and without chemical reactions - Calculations and application of heat of reaction, Combustion, Formation, Neutralization - Calculation and application of heat of solution, Enthalpy concentration chart, Calculation of theoretical and actual flame temperature.

UNIT 5: Applications of Material and Energy Balances **9 Hours**

Applications of material and energy balances to various process industries especially combustion of solids, liquids and gaseous fuels.

Total: 45 Hours

Textbook(s):

1. B. I. Bhatt, and S. M. Vora, Stoichiometry - Tata McGraw-Hill Publishing Company, New Delhi, 2010 (5^{th} Edition)

2. P. M. Doran, Bioprocess Engineering Principles- Academic Press (An Imprint of Elsevier), New Delhi, 2012 (2^{nd} Edition)

Reference(s):

1. D.M. Himmelblau, Basic Principles and Calculations in Chemical Engineering- Prentice-Hall of India, New Delhi, 2012 (8^{th} Edition).

2. N. Bruce, Handbook of Chemical Reactor Design Optimization and Scale up - McGraw Hill New York, 2002.

217CHE2102	Transfer Operations I	L	T	P	C
		3	0	0	4
Prerequisite: Nil	**Course Category:** Minors **Course Type:** Theory				

Course Objective(s):

To impart the fundamental concepts of fluid statics, pressure distribution and dimensional Analysis, to enable students to compute velocity profile, friction factor and head loss in pipes and fittings, to impart the knowledge of metering and transportation of fluids and fluid moving machinery performance and to understand basic principles of particle preparation, their characterization and equipments.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: understand the fundamental concepts in fluids statics and to use dimensional analysis for scaling experimental results

CO2: analyze frictional flow in pipes and piping networks and to compute the head loss and power requirements for chemical process equipments

CO3: select the metering equipments and fluid moving machinery for an appropriate chemical engineering operations

CO4: understand the basic principles of particles preparation and their characterization

CO5: have knowledge on different size reducing equipment and power requirements during size reduction

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1												
CO2												
CO3												
CO4												
CO5												

UNIT 1: Introduction **9 Hours**

Properties of fluids and concept of pressure: Introduction - Nature of fluids - physical properties of fluids - types of fluids. Fluid statics: Pressure - density - height relationships. Pressure Measurement. Units and Dimensions - Dimensional analysis.

UNIT 2: Momentum Balance and their Applications **9 Hours**

Kinematics of fluid flow: Stream line -stream tube - velocity potential. Newtonian and non-Newtonian fluids - Time dependent fluids - Reynolds number - experiment and significance - Bernoulli's equation - Correction for fluid friction -Correction for pump work.

UNIT 3: Flow of Incompressible Fluids Through Ducts **9 Hours**

Flow of incompressible fluids in pipes - laminar and turbulent flow through closed conduits-velocity profile & friction factor for smooth and rough pipes - Head loss due to friction in pipes, fitting etc. Transportation and Metering: Measurement of fluid flow: Orifice meter, venturi meter, pitot tube, rotameter.

UNIT 4: Energy Balances in Fluid Flow **9 Hours**

Mechanical Energy and Efficiency, Bernoulli Equation, Acceleration of a Fluid Particle, Force Balance across Streamlines, Unsteady, Compressible Flow, Static, Dynamic, and Stagnation Pressures, Limitations on the Use of the Bernoulli Equation, Hydraulic Grade Line (HGL) and Energy Grade Line (EGL).

UNIT 5: Characteristics of Particulate Material **9 Hours**

Characteristics of Particulate Material: Properties and characterization of particulate solids, analysis and technical methods for size and surface area distribution of powder; Flow properties of particulates. Introduction to size reduction equipment, energy and power requirement in milling operations.

Total: 45 Hours

Textbook(s):

1. Noel de Nevers, Fluid Mechanics for Chemical Engineers, McGraw Hill, New York, 1991 (2nd Edition).

2. W. L. McCabe, J. C. Smith, and P. Harriot, Unit Operation of Chemical Engineering, McGraw Hill, New York, 2005 (7th Edition).

3. B. R. Munson, and D. F. Young, T. H. Okiishi, Fundamentals of Fluid Mechanics, Wiley Publications, 2006 (5th Edition).

4. M. White, Fluid Mechanics, Tata McGraw Hill, New Delhi, 2016 (8th Edition).

5. V. Gupta and S. K. Gupta, Fundamentals of Fluid Mechanics, New Age International, 2011 (2nd Edition).

Reference(s):

1. R. L. Panton, Incompressible Flow, Wiley Publications, 2005 (3rd Edition).

2. R. B. Bird, W. E. Stewart, and E. N. Lightfoot, Transport Phenomena - Wiley Publications, 2007 (Revised 2nd Edition).

3. J. H. Harker, J. F. Richardson, J. M. Coulson, and R. P. Chhabra, Coulson and Richardson’s Chemical Engineering Series Volume I - Butterworth-Heinemann - 1999 (6th Edition)

217CHE3101	Transfer Operations II	L	T	P	C
		3	0	0	4
Prerequisite: Transfer Operations I	**Course Category:** Minors **Course Type:** Theory				

Course Objective(s):

To impart the basic concepts of transfer operations, and to understand the transfer operations and equipments in process industries.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: acquire sufficient knowledge in the concepts of mass transfer operations

CO2: analyze the mass transfer operations and apply in the process industries

CO3: acquire sufficient knowledge in the concepts of heat transfer operations

CO4: analyze the heat exchanger operations and apply in the process industries

CO5: develop skills in operating the transfer equipments in Process industries

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1												
CO2												
CO3												
CO4												
CO5												

UNIT 1: Principles of Mass transfer **9 Hours**

Fick's law of diffusion, unsteady state diffusion, Convective mass transfer, Inter phase mass transfer and mass transfer coefficients, Mass transfer theories. Equilibrium stages and transfer units, Equipments-Plate and Packed columns, stage efficiency.

UNIT 2: Unit Processes in Mass Transfer **9 Hours**

Principle and theory of Gas absorption, Distillation- Types of distillation, continuous fractionation, Liquid-Liquid extraction, Leaching, Adsorption.

UNIT 3: Basic concepts of heat Transfer **9 Hours**

Heat conduction, types and governing equation, natural and forced convection heat transfer coefficient, thermal boundary layer, laws of thermal radiation, shape factor, radiation shield, greenhouse effect.

UNIT 4: Heat exchanger **9 Hours**

Types of heat exchangers, charts, performance analysis of heat exchangers.

UNIT 5: Simultaneous Heat and Mass Transfer **9 Hours**

Humidification- cooling towers, Drying, CrystallizationSuper saturation theory, crystallizers, evaporators and condensers.

Total: 45 Hours

Textbook(s):

1. R. E. Treybal, Mass Transfer Operations, McGraw Hill Book Co., New York, 1981 (3rd Edition).

2. D. Q. Kern, Process Heat Transfer, McGraw Hill Publishing Co., 1950.

Reference(s):

1. W. L. Mccabe, J. C. Smith and P. Harriot, Unit Operations in Chemical Engineering, McGraw Hill Book Co., New York, 2004 (7th Edition).

2. W. L. Badger and J. T. Banchero, Introduction to Chemical Engineering, McGraw Hill Book Co., New York, 1955.

3. Binay. K. Dutta, Heat Transfer Principles and applications, Prentice Hall of India Pvt. Ltd., 2003.

217CHE3102	Chemical Reaction Engineering	L	T	P	C
		3	0	0	4
Prerequisite: Nil	**Course Category:** Minors **Course Type:** Theory Course				

Course Objective(s):

To understand the conceptual design of reactors and its non-ideal behavior.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Describe the kinetics of reactions

CO2: Interpret reactor data and rate equation

CO3: Identify ideal reactors and explain the various aspects of design for single reactions

CO4: Explain the various aspects of design for multiple reactions

CO5: Analyse non-ideal behavior of reactors with suitable models

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H	M										
CO2	H		H	H								
CO3	H		H	M					L	L		
CO4	H		H	M					L	L		
CO5	H		H	M								

UNIT 1: Reaction Kinetics **9 Hours**

Chemical kinetics - Classification of reactions, variables affecting rate of reaction, definition of reaction rate - Kinetics of homogeneous reactions - Concentration dependent terms of rate equation - Elementary and non-elementary reactions, kinetic view of equilibrium for elementary reactions - Molecularity and order of reaction, representation of reaction rates - Testing kinetics models - Temperature dependency of rate - Rate of reaction predicted by theories

UNIT 2: Interpretation of Reactor Data and Rate Equation **9 Hours**

Interpretations of reactor data - Constant volume batch reactor - Integral methods of analysis - Autocatalytic reactions - First and second order reversible reactions - Differential method of analysis - Variable volume batch reactor - Temperature and reaction rate - Search for rate equation

UNIT 3: Ideal Reactors **9 Hours**

Ideal Reactors - Reactor design, batch reactor, semi batch reactor, single ideal reactors - Performance equations for batch, plug, mixed reactor - Design for simple reactions - Size comparison of single reactors, general graphical comparison - Multiple reactor systems - Mixed flow reactor of different type in series - Reactors of different types in series - Recycle reactor

UNIT 4: Multiple Reactions **9 Hours**

Design of reactor for multiple reactions - Reaction in series and parallel - Qualitative and quantitative treatment about product distribution - Successive irreversible reactions of different orders - kinetics of series-parallel reactions

UNIT 5: RTD Studies **9 Hours**

Basics of non-ideal flow- RTD in non-ideal flow; non-ideal flow models- Tank in series model and Axial Dispersion Model, conversion in non-ideal reactors

Total: 45 Hours

Textbook(s):

1. O. Levenspiel, Chemical Reaction Engineering, Wiley Publications, New York, 2019 (3rd Edition).

2. G. F. Froment, K. B. Bischoff, Chemical Reactor Analysis and Design, Wiley Publications, New York, (3rd Edition).

3. H. S. Fogler, Elements of Chemical Reaction Engineering, Prentice Hall of India, New Delhi, 2016 (5thedition).

Reference(s):

1. E. Davis Mark, J. J. Davis Robert, Fundamentals of Chemical Reaction Engineering, McGraw Hill, New York, 2003.

2. N. Bruce, Handbook of Chemical Reactor Design Optimization and Scale up - McGraw Hill, New York, 2002.

217CHE2103	Chemical Technology	L	T	P	C
		3	0	0	4
Prerequisite: Nil	**Course Category:** Minor **Course Type:** Theory				

Course Objective(s):

To understand the basic process of chemical Engineering and its applications in various aspects.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Explain the processing of natural products

CO2: Describe about microbial processes and edible oil refining process

CO3: Enumerate the manufacturing processes of chloro-alkali and sulfur chemicals

CO4: Explain the manufacturing processes of industrial gases, petro and silicate chemicals

CO5: Describe the manufacturing processes of fertilizer and agrochemicals

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H		M				L					
CO2					M						M	
CO3		H						L				
CO4					H					L		
CO5			H			M						L

UNIT 1: Natural Products Processing **9 Hours**

Production of pulp, paper and rayon, Manufacture of sugar, starch and starch derivatives, Gasification of coal and chemicals from coal.

UNIT 2: Fermentation & Edible Oil Refining Processes **9 Hours**

Industrial microbial processes: Fermentation processes for the production of ethyl alcohol, citric acid and antibiotics, Edible oil refining processes: Refining of edible oils and fats, fatty acids, Soaps and detergents.

UNIT 3: Chloro-Alkali & Sulfur Industries **9 Hours**

Alkalis and Acids: Chloro - alkali Industries: Manufacture of Soda ash, Manufacture of caustic soda, chlorine, and common salt, Mining of sulphur, Manufacture of Sulphur, Sulphuric acid and Hydrochloric acid.

UNIT 4: Industrial Gases, Petrochemical & Silicate Industries 9 Hours

Industrial gases: Oxygen, Nitrogen, and Hydrogen - Basic block diagram and simplified process flow diagram for manufacture of Petrochemicals: C1, C2, C3, C4, benzene, toluene, xylene - Silicate industry: Portland cement, Glasses, Ceramics.

UNIT 5: Fertilizers and Agrochemical Industries 9 Hours

Fertilizers: Nitrogen Fertilizers; Synthetic ammonia, nitric acid, Urea, Phosphorous Fertilizers: Phosphate rock, phosphoric acid, super phosphate and Triple Super phosphate.

Total: 45 Hours

Textbook(s):

1. George T. Austin, Shreve’s Chemical Process Industries - McGraw-Hill International, Singapore, 2017 (5th Edition)

2. M. Gopala Rao and Marshall Sittig - Dryden’s Outlines of Chemical Technology - East-West Pvt Ltd., New Delhi, 1997 (3rd Edition)

Reference(s):

1. J. A. Kent, Kent and Riegel's Handbook of Industrial Chemistry and Biotechnology – Springer Netherlands, 2007 (11th Edition)

2. M. Farhat Ali and Bassam El Ali - Handbook of Industrial Chemistry: Organic Chemicals – McGraw Hill, New York, 2004 (1st Edition)

3. G. N. Pandey, Textbook of Chemical Technology - Vol. I & II, Vikas Publishing House, New Delhi, 2018 (2nd Edition)

leaky mode polarizer, metal clad polarizer; Phase modulator; Optical switch; Acousto-optic devices: mode converter, tunable wavelength filter, Bragg type modulator, Bragg type deflector; Magneto-optic devices: TE-TM mode converter, modulators and switches, SiO_2/Si based thin film devices, Ti/LiNbO3 based optical devices, Proton exchange based optical devices.

UNIT 3: Optoelectronic Devices **9 Hours**

Semiconductor Lasers: heterojunction and surface emitting lasers, quantum well lasers; Modulation of lasers; Photodetectors: PIN, MSM, Avalanche photodiodes; Optoelectronic modulation and switching devices; Electro-optic Devices; Optoelectronic Integrated circuits.

UNIT 4: Nanostructures **9 Hours**

Nanocrystals: Electronic states, properties and fabrication; Nanomaterials – preparation methods - Chemical vapour deposition- Sol-gel methods - Optical properties of nanostructures; nano photodetector, nano transistor.

UNIT 5: Quantum Devices **9 Hours**

Low-dimensional structures: Quantum wells, Quantum wires, and Quantum dots; Density of states in low-dimensional structures; Resonant tunneling phenomena and applications in diodes and transistors; Applications of quantum devices: quantum well and quantum dot lasers, ultra-fast switching devices, high density memories, dc and rf squids, multi-state logic circuits, long wavelength detectors.

Total: 45 Hours

Textbook(s):

1. Joachim Piprek, Semiconductor optoelectronic devices, Academic press Hardbound, 2003.

2. A. K. Ganguly, Optoelectronic devices and circuits, Narosa publication, 2007.

3. Shun Lien Chuang, Physics of Optoelectronic Devices, Wiley-Inter Science, 1995 (1^{st} Edition).

Reference(s):

1. Jia- Ming Liu, Photonic Devices, Cambridge University Press, 2005.

2. Goure and Verrier, Optical Fibre Devices, Taylor & Francis, 2001 (1^{st} Edition).

Honors Courses

218CHE2101	Advanced Chemical Engineering Thermodynamics	L	T	P	C
		3	0	0	3
Prerequisite: Chemical Engineering Thermodynamics	**Course Category:** Honors **Course Type:** Theory				

Course Objective(s):

In any chemical process, often one encounter interaction between phases where transfer of species takes place from one phase to other. There exist several situations of vapor-liquid, liquid-liquid, vapor-liquid-liquid, solid-liquid equilibria in chemical engineering processes. Often these situations are dealt with assumption of ideal behavior and binary systems but in reality non-ideality and multicomponent mixtures exists and accordingly one has to deal with such situations. This course offers step-by-step understanding of required thermodynamic properties to handle such equilibrium cases and explore possible ways of solving problems associated with non-ideality in VLE, LLE, VLLE and SLE for multicomponent mixtures.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Familiar with the structure of engineering materials (metals, polymers, ceramics, and composites) at the atomic and microstructural levels.

CO2: Familiar with the relationships between structure and properties for engineering materials.

CO3: locate materials selection data and information about the cost and availability of materials.

CO4: Familiar with the rationale for selecting materials based on materials and process selection charts.

CO5: Apply their knowledge of materials science to the selection of metals and alloys, polymers, ceramics and composites.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H	H		M						M		
CO2	H	M						H				L
CO3			H	H				M				
CO4				H				M	H		L	
CO5					H					M		

UNIT 1: Introduction **9 Hours**

Basic Concepts of Thermodynamics, 1st, 2nd, and 3rd Law of thermodynamics, Free Energy Functions, Equilibrium and Stability Conditions, Thermodynamics of Gases, Liquids and Solids.

UNIT 2: Equilibrium and Phases **9 Hours**

Phase and Chemical Equilibrium, Nonelectrolyte Solutions, Phase Transitions and Critical Phenomena, Principles of Statistical Mechanics, Statistical Mechanics in Thermodynamics, Molecular Partition Functions.

UNIT 3: Thermodynamic Analysis **9 Hours**

Application in analysis of energy and efficiency of equipment, flow through equipment. State and behavior of materials, degree of freedom analysis.

UNIT 4: Thermodynamic Properties **9 Hours**

Material properties as a function of conditions. Relationships between material properties, and changes in material properties. Equilibrium properties of materials: pure materials, and mixtures. A-priori probability postulate, ergodic hypothesis.

UNIT 5: Macroscopic Thermodynamics **9 Hours**

Introduction to micro canonical, canonical and grand canonical ensembles, derivation of physical properties for pure components and mixtures, ideal gas and lattice gas, virial coefficient calculations. Crystal structures, solutions, modeling and analysis of adsorption phenomena, relating them to macroscopic thermodynamics.

Total: 45 Hours

Textbook(s):

1. J. M. Smith H. C. Van Ness, M. M. Abbot, and B. Bhatt, Introduction to Chemical Engineering Thermodynamics - McGraw Hill, New York, 2009 (8th Edition)

2. Paul Stevenson, Thermodynamics for Chemical Engineering: A Process Approach - CRC Press, Taylor & Francis Group, 2019 (1st Edition)

3. J. R. Elliot, and C. T. Lira, Introductory Chemical Engineering Thermodynamics - Pearson Education India, 2013 (2nd Edition)

Reference(s):

1. M. J. Moran, H. N. Shapiro, D. D. Boettner and M B Bailey, Principles of Engineering Thermodynamics - Wiley Publications, 2015 (8th Edition)

2. P. K. Nag, Engineering Thermodynamics - McGraw Hill, New York, 2017 (6th Edition)

3. Y. A. Cengel, M. A. Boles, and M. Kanoglu. Thermodynamics - An Engineering Approach - McGraw Hill, New York, 2019 (9th Edition)

218CHE2102	Advanced Heat Transfer	L	T	P	C
		3	0	0	3
Prerequisite: Heat Transfer	**Course Category:** Honors **Course Type:** Theory				

Course Objective(s):

To study the heat transfer advanced functions through convection, conduction and radiation modes and apply the understanding to design heat exchangers.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Understand the concept of thermal conduction; should be able to get analytical solutions for 2D/3D steady heat conduction problems by using variable separation method.

CO2: Understand the heat conduction with phase change, and knowing how to solve it.

CO3: Application of governing equations for convection heat transfer; and knowing the dimensionless parameters

CO4: Analyzing the external and internal laminar flow heat transfer using boundary layer concept

CO5: Understanding of the boiling and condensation mechanism; Thermal performance analysis for a heat pipe.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H	L	M									
CO2	H	H	L	H	M							L
CO3	H	H	L	H	M						L	
CO4	H	H	L	H	M							
CO5		L	L	H					H	M	M	

UNIT 1: Conduction and Convection **9 Hours**

Heat conduction, transient and steady state heat conduction. Convective heat transfer, conservation equations, boundary layer approximations. Forced convective laminar and turbulent flow solutions. Natural convection solutions, correlations.

UNIT 2: Radiation **9 Hours**

Radiation heat transfer, estimation of view factors and emissivity factors for different situation. Combined conduction, convention and radiation heat transfer and its applications.

UNIT 3: Phase change **9 Hours**

Heat Transfer with phase change: condensation – mechanism, controlling parameters. Nusselt Theory; solution to laminar film modifications, influence of other parameters.

UNIT 4: Flow Correlations **9 Hours**

correlations for single horizontal tube, vertical bank of horizontal tubes, other configurations. Dropwise condensation. Boiling mechanisms regimes. Selection and design of equipment with phase transformation.

UNIT 5: Heat Exchanger Design **9 Hours**

Advances in heat exchanger design and compact heat exchangers, Heat transfer in liquid metals. Heat transfer in packed and fluidized beds.

Total: 45 Hours

Textbook(s):

1. J. P. Holman, Heat Transfer, McGraw Hill, Singapore, 2002 (9th Edition).

2. Donald Q. Kern, Process Heat Transfer, Tata McGraw Hill, New Delhi, 1997 (1st Edition Reprint).

3. Binay K Dutta, Heat Transfer: Principles and Application, PHI Learning Pvt. Ltd., 2000.

4. M. N. Ozisik, Heat Transfer: A Basic Approach, McGraw-Hill, Singapore, 1985.

Reference(s):

1. F. P. Incropera, D. P. Dewitt, T. L. Bergman, and A. S. Lavine, Introduction to Heat Transfer, Wiley Publications, Singapore, 2006 (5th Edition).

2. A. Bejan, Convective Heat Transfer, Wiley Publications, Singapore, 2006 (3rd Edition).

3. F. Kreith, R. M. Manglik, and M. S. Bohn, Principles of Heat Transfer, Cengage Learning, 2009 (7th Edition).

218CHE2103	**Advanced Transport Phenomena**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**
Prerequisite: Fluid mechanics	**Course Category:** Honors **Course Type:** Theory				

Course Objective(s):

To provide comprehensive knowledge of advanced topics in transport phenomena.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: explain flow over different bodies

CO2: explain the chemically reactive mass transport behaviors

CO3: apply phase equilibria parameters in the estimation of transport properties

CO4: perform mass transfer analysis involving different phases

CO5: perform heat transfer analysis for non-steady state and non-isothermal systems.

Mapping of course outcomes:

CO/PO	**PO**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
CO1	H	H						M	L			
CO2		H			M		H					
CO3		H										
CO4		H	H	H					M	L		
CO5	M	H		H					M	M		

UNIT 1: Transport Past Immersed Bodies **9 Hours**

Laminar and turbulent boundary layers, heat and mass transfer during boundary layer flow past a flat plate, flow over cylinders and spheres, drag coefficient correlations. Flow phenomena with gas-liquid and liquid-liquid mixtures.

UNIT 2: Mass Transfer with Chemical Reaction **9 Hours**

Enhancement of mass transfer due to chemical reaction, gas-liquid reactions in agitated vessel, wetted wall columns and packed beds. Determination of interfacial area and mass transfer coefficient. Application of mass transfer theories to gas-liquid mass transfer with chemical reaction.

UNIT 3: Phase equilibria **9 Hours**

Solid-liquid, gas-solid, liquid-solid, vapour-liquid equilibria, effect of temperature, pressure and third component on the equilibrium.

UNIT 4: Fluid-Solid Mass Transfer **9 Hours**

Adsorption and ion exchange, fixed bed adsorption, break-through curve and bed utilization, design of ion exchangers.

UNIT 5: Heat Transfer in Turbulent and Non-Isothermal Systems **9 Hours**

Temperature distribution in turbulent flow and interphase–transport in non-isothermal systems.

Total: 45 Hours

Textbook(s):

1. R. B. Bird, W. E. Stewart, and E. N. Lightfoot, Transport Phenomena, Wiley Publications, 2007 (Revised 2nd Edition).

2. R. S. Brodkey, and H. C. Hershey, Transport Phenomena: A Unified Approach, Volume 1 & 2, McGraw Hill, New York, 2003 (2nd Edition).

Reference(s):

1. C. J. Geankopolis, Transport Processes and Separation Process Principles (Includes Unit Operations), Prentice Hall of India Pvt. Ltd., New Delhi, 2003 (4th Edition).

2. W. M. Deen, Analysis of Transport Phenomena, Oxford University Press, 2013 (2nd Edition).

3. J. R. Welty, C. E. Wicks, G. L. Rorrer. and R. E. Wilson, Fundamentals of momentum, heat, and mass transfer, Wiley Publications, 2010 (5th Edition).

218CHE2104	PROCESS SAFETY MANAGEMENT	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** Honors **Course Type:** Theory				

Course Objective(s):

To inculcate the importance of process safety practices, to imbibe an extensive knowledge on the management of safety and to provide technical inputs pertaining to safety.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: identify the process hazards in chemical industries.

CO2: acquire knowledge on fire and explosion safety.

CO3: identify as well as analyze the different types of hazard

CO4: handle leaks and will have knowledge on its management

CO5: have knowledge on real time incidents that are occurred in the past.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H			H	H	H	H				H	
CO2	H	H	H		H	H	H	H		H	H	
CO3	H	H	H		H	H	H	M			H	
CO4	H	H	H	M	H	H	H	H		H	H	
CO5	H	M	H		H	H	H	H		M	H	H

UNIT 1: Introduction **9 Hours**

Industrial processes and hazards potential, mechanical electrical, thermal and process hazards. Safety and hazards regulations, Industrial hygiene. Factories Act, 1948 and Environment (Protection) Act, 1986 and rules thereof.

UNIT 2: Fire and Explosion **9 Hours**

Shock wave propagation, vapour cloud and boiling liquid expanding vapours explosion (VCE and BLEVE), mechanical and chemical explosion, multiphase reactions, transport effects and global rates. Preventive and protective management from fires and explosion - inerting, static electricity passivation, ventilation, and sprinkling, proofing, relief systems – relief valves, flares, scrubbers.

UNIT 3: HAZOP & HAZAN **9 Hours**

Hazards identification-toxicity, fire, static electricity, noise and dust concentration; Material safety data sheet, hazards indices- Dow and Mond indices, hazard operability (HAZOP) and hazard analysis (HAZAN).

UNIT 4: Leaks and Leakages **9 Hours**

Spill and leakage of liquids, vapors, gases and their mixture from storage tanks and equipment; Estimation of leakage/spill rate through hole, pipes and vessel burst; Isothermal and adiabatic flows of gases, spillage and leakage of flashing liquids, pool evaporation and boiling; Release of toxics and dispersion. Naturally buoyant and dense gas dispersion models; Effects of momentum and buoyancy; Mitigation measures for leaks and releases.

UNIT 5: Case Studies **9 Hours**

Flix borough, Bhopal, Texas, ONGC offshore, HPCL Vizag and Jaipur IOC oil storage depot incident; Oil, natural gas, chlorine and ammonia storage and transportation hazards.

Total: 45 Hours

Textbook(s):

1. D. A. Crowl and J. F. Louvar Chemical Process Safety: Fundamentals with Applications, Prentice Hall, 2001 (2^{nd} Edition).

2. S. Mannan, Lee’s Loss Prevention in the Process Industries- Vol. I, II, and III, Butterworth Heinemann, 2004 (2^{nd} Edition).

Reference(s):

1. M. Tweeddale, Managing Risk and Reliability of Process Plant - Gulf Professional Publishing, 2003 (1^{st} Edition).

218CHE2105	Fluidization Engineering	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** Honors **Course Type:** Theory				

Course Objective(s):

To understand the concepts and applications of fluidized bed systems to develop the models for fluidized bed systems.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Explain fluidization behavior

CO2: Estimate pressure drop, bubble size, TDH, voidage, heat and mass transfer rates for the fluidized beds

CO3: Write model equations for fluidized beds

CO4: Design gas-solid fluidized bed reactors.

CO5: Explain heart transfer in fluidized bed.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1	H											
CO2	H	H										
CO3	M			M	M							
CO4	H		M	M	H				L	L		
CO5			H	H								

UNIT 1: Fundamentals of Fluidization **9 Hours**

Introduction to fluidized bed systems. Fundamentals of fluidization. Industrial applications of fluidized beds - Physical operations. Synthesis reactions, cracking and reforming of hydrocarbons, Gasification, Carbonization, Gas-solid reactions, calcining and clinkering.

UNIT 2: Design of Fluidized Bed **9 Hours**

Gross behavior of fluidized beds. Minimum and terminal velocities in fluidized beds. Types of fluidization. Design of distributors. Voidage in fluidized beds. TDH, variation in size distribution with height, viscosity and fluidity of fluidized beds, Power consumption.

UNIT 3: Analysis of bubble and emulsion Phase **9 Hours**

Davidson's model, Frequency measurements, bubbles in ordinary bubbling bed model for bubble phase. Emulsion phase: Experimental findings. Turn overrate of solids- Bubbling bed model for emulsion phase. Interchange co-efficient.

UNIT 4: Flow Pattern in Fluidized Beds **9 Hours**

Flow pattern of gas through fluidized beds- Experimental findings - The bubbling bed models for gas inter change Interpretation of Gas mixing data. Heat and Mass Transfer between fluid and solid: Experiment findings on Heat and Mass Transfer. Heat and mass transfer rates from bubbling bed model.

UNIT 5: Heat Transfer In Fluidized Beds **9 Hours**

Heat transfer between fluidised beds and surfaces: Experiment finding theories of bed heat transfer comparison of theories. Entrainment of or above TDH, model for Entrainment and application of the entrainment model to elutriation.

Total: 45 Hours

Textbook(s):

1. F.A. Zenz, and D. F. Othmer, Fluidization and Fluid Particle Systems (Chemical Industries), CRC Press, New York, 2003.

2. Octave Levenspiel, and Kunii Daizeo, Fluidization Engineering (Chemical Engineering Series), 2001 (2nd Edition)

Reference(s):

1. J.M. Coulson, J. F. Richardson, J. R. Backhurst, and J. M. Harker, Coulson and Richardson's Chemical Engineering, Vol. I, Butterworth-Heinemann, Oxford, 1999 (6th Edition).

2. W. L. Badger and J. T. Banchero, Introduction to Chemical Engineering, Tata McGraw Hill, 1997 (1st edition).

218CHE2106	Biochemical Engineering	L	T	P	C
		3	0	0	3
Prerequisite: Nil	**Course Category:** Honors **Course Type:** Theory				

Course Objective(s):

To impart the basic concepts of biochemical engineering and develop understanding about biochemistry and bioprocesses.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Enhance knowledge in the aspects of cell structure and its functions

CO2: Identify the importance of bimolecular in metabolic processes.

CO3: Analyze the kinetics of enzymatic reactions and their inhibitions.

CO4: Evaluate and model the cell growth kinetics in a bioreactor.

CO5: Design a bioprocess with various unit operations involved in it.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1			M									
CO2					M		H					
CO3							M					
CO4			H				M					
CO5	M		H									

UNIT 1: Introduction **9 Hours**

Introduction to Bioscience: Types of Microorganisms: Structure and function of microbial cells. Fundamentals of microbial growth, batch and continuous culture. Isolation and purification of Enzymes from cells. Cell Growth Measurement.

UNIT 2: Bioenergetics **9 Hours**

Functioning of Cells and Fundamental Molecular Biology: Metabolism and bio-energetics, Photosynthesis, carbon metabolism, EMP pathway, tricarbocyclic cycle and electron transport chain, aerobic and anaerobic metabolic pathways. Synthesis and regulation of biomolecules, fundamentals of microbial genetics, role of RNA and DNA.

UNIT 3: Enzyme Engineering **9 Hours**

Enzyme kinetics: Simple enzyme kinetics, Enzyme reactor with simple kinetics. Inhibition of enzyme reactions. Other influences on enzyme activity. Immobilization of enzymes. Effect of mass transfer in immobilized enzyme particle systems. Industrial applications of enzymes.

UNIT 4: Reaction Engineering **9 Hours**

Cell kinetics and fermenter design: Growth cycle for batch cultivation, Stirred-tank fermenter, Multiple fermenters connected in series. Cell recycling. Structured Model.

UNIT 5: Bioreactors **9 Hours**

Introduction to Bioreactor design: Continuously Stirred aerated tank bioreactors. Mixing power correlation. Determination of volumetric mass transfer rate of oxygen from air bubbles and effect of mechanical mixing and aeration on oxygen transfer rate, heat transfer and power consumption. Multiphase bioreactors and their applications. Downstream processing and product recovery in bioprocesses.

Total 45 Hours

Reference(s):

1. J. E. Bailey and D. F. Ollis, Biochemical Engineering Fundamentals, McGraw Hill, New York , 1986 (2nd Edition).

2. Trevan, Boffey, Goulding and Stanbury, Biotechnology, Tata McGraw Hill Publishing Co., New Delhi, 1987.

3. H. W. Blanch and D. S. Clark, Biochemical Engineering, Marcel Dekker, Inc., New York, 1996.

4. M. L. Shuler and F. Kargi, Bio Process Engineering: Basic concepts, Prentice Hall of India, New Delhi, 2002 (2nd Edition).

218CHE2107	Environmental Impact Assessment	L	T	P	C
		3	0	0	2
Prerequisite: Nil	**Course Category:** Honors **Course Type:** Theory				

Course Objective(s):

This course will introduce students to the theory and practice of environmental impact assessment (EIA), the systematic identification and evaluation of the potential effects on the physical, biological, cultural, and socioeconomic components of the environment of proposed actions such as projects, plans, programs, and legislation.

Course Outcomes(s):

At the end of the course the students would be able to

CO1: Understand the concept and basic process of environmental impact assessment

CO2: Develop a critical awareness of factors which affect the use of EIA.

CO3: Familiarity with specific models and methodologies used for impact prediction.

CO4: Carry out simple EIA

CO5: Prepare the various documents required by state and federal regulations.

Mapping of course outcomes:

CO/PO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
CO1												
CO2												
CO3												
CO4												
CO5												

UNIT 1: Introduction **9 Hours**

Definition of environment: Environment, Background, Sustainable development - Environmental Impact Assessment, History of Environmental Impact Assessment, Definition of Environmental Impact Assessment, Benefits and Directive of Environmental Impact Assessment.

UNIT 2: The Environmental Impact Assessment Process **9 Hours**

Types of Assessments: Environmental Assessments. Environmental Impact Statement - Basic Steps in the Process: Alternative, Screening, Scoping, Impact analysis, Mitigation, Follow up, Public involvement.

UNIT 3: Impact prediction methodologies and mitigation measures 9 Hours

Based on Air, Surface and ground water, Biologic, Noise, Cultural and socioeconomic.

UNIT 4: Case Study 9 Hours

Presentation of EIA procedures for different cases.

UNIT 5: Special Topics 9 Hours

Cultural and Social Impact Assessment for specific situations, Strategic Environmental Appraisal, Environmental Management Plan.

Total 45 Hours

Text Book(s):

1. A. Chadwick, Introduction to Environmental Impact Assessment, Taylor & Francis, 2007.

2. Larry W. Canter, Environmental Impact Assessment, McGraw Hill Inc. Singapore, 1996.

Reference(s):

1. R. Therirvel, E. Wilson, S. Hompson, D. Heaney, and D. Pritchard, Strategic Environmental Assessment, Earthscan, London, 1992

2. Paul, A Erickson, A Practical Guide to Environmental Impact Assessment, Academic Press, 1994.