Curriculum Undergraduate Programme

B. Tech. Chemical Engineering

(2012 Batch onwards)

Department of Chemical Engineering

Dr. B. R. Ambedkar National Institute of Technology
Jalandhar–144011, Punjab, India

Phone: 0181-2690301, 302 (Ext. 2401) **Fax: 0181-2690932** **Website: www.nitj.ac.in**

PREFACE

With rapidly changing industrial scenario and technological advances that have taken place in the field of Chemical Engineering has been revolutionalized. This needs upgradation and updating the existing academic programmes so that trained human resources are competent to meet requirements of today's industries. Accordingly the Department of Chemical Engineering has come forward to restructure the academic programmes stipulated under the credit based system.

The Department has tried its best to prepare a Model Curriculum and Syllabi for Four year under graduate programme for B. Tech. Degree in Chemical Engineering. It is really challenging to evolve a common programme for this discipline that meets the need of national and international industries and research establishments. However, with the rich experience of successful experimentation with above idea for over forty years, the task of development of a model curriculum could be possible.

The suggested curriculum possesses the following features:

- The suggested curriculum is in conformity with IIT/AICTE norms with emphasis on analysis and design of industrial processes required to work in control environment.
- The graduates turned out have to be acceptable by national and international industry and academic/research establishments.
- The programme has to be forward looking in context of the rapid changing scenario of science and technology which provides a proper balance in teaching of basic sciences, social sciences and management, engineering sciences and technical arts, technologies and their applications.
- Core subjects have been selected to cover all those, which are essential in training of Chemical graduates.
- The curriculum presents flexibility so that new programmes started with reasonable sources can be managed with a scope of further updating as the resource position improves.

I take this opportunity to express my deep appreciation to members of the Senate for their valuable suggestions and critical comments in finalizing the curriculum and Professor S. K. Das, Director, NIT Jalandhar for his initiative and direction. It is hoped that the curriculum compiled in the form of the booklet will be of immense help to the students and the faculty in smooth running the under graduate programme in Chemical Engineering. I thank all the members of Board of Studies for Chemical Engineering for their help and cooperation rendered in bringing out this curriculum in time.

(Dr. Ajay Bansal)
Associate Professor and Head
Department of Chemical Engineering

Department of Chemical Engineering

B Tech Teaching Scheme

(III to VIII Semester)

	III Semester	**L**	**T**	**P**	**C**		**IV Semester**	**L**	**T**	**P**	**C**
MAX-201	Mathematics II	3	1	0	4	MAX-202	Mathematics III	3	1	0	4
CSX-207	Object Oriented Programming	3	0	0	3	PHX-204	Material Science and Engineering	3	1	0	4
CHX-201	Fluid Mechanics	3	1	0	4	CHX-202	Chemical Technology	3	1	0	4
CHX-203	Mechanical Operations	3	1	0	4	CHX-204	Chemical Engineering Thermodynamics	3	1	0	4
CHX-205	Chemical Process Calculations	3	1	0	4	CHX-206	Heat Transfer Operations	3	1	0	4
CSX-227	Object Oriented Programming Lab	0	0	2	1	PHX-214	Material Science and Engineering Lab	0	0	2	1
CHX-221	Fluid Mechanics Lab	0	0	3	2	CHX-222	Chemical Technology Lab	0	0	3	2
CHX-223	Mechanical Operations Lab	0	0	3	2	CHX-224	Heat Transfer Lab	0	0	3	2
	Total	**15**	**4**	**8**	**24**		**Total**	**15**	**5**	**8**	**25**
	V Semester	**L**	**T**	**P**	**C**		**VI Semester**	**L**	**T**	**P**	**C**
CYX-301	Nano Science and Nano Technology	3	1	0	4	CHX-302	Instrumentation and Process Control	3	1	0	4
CHX-301	Mass Transfer Operations I	3	1	0	4	CHX-304	Mass Transfer Operations II	3	1	0	4
CHX-303	Chemical Reaction Engineering I	3	1	0	4	CHX-306	Chemical Reaction Engineering II	3	1	0	4
CHX-305	Hydrocarbon Engineering	3	1	0	4	CHX-308	Environmental Engineering	3	1	0	4
CHX-307	Energy Technology	3	1	0	4	CHX-310	Process Engineering and Economics	3	1	0	4
CHX-321	Process Equipment Design	1	0	2	2	CHX-322	Mass Transfer Lab	0	0	3	2
CHX-323	Energy Technology Lab	0	0	3	2	CHX-324	Reaction Engineering and Control Lab	0	0	3	2
						CHX-326	Environmental Engineering Lab	0	0	3	2
	Total	**16**	**5**	**5**	**24**		**Total**	**15**	**5**	**9**	**26**
	VII Semester	**L**	**T**	**P**	**C**		**VIII Semester**	**L**	**T**	**P**	**C**
CHX-401	Transport Phenomena	3	1	0	4	CHX-402	Modeling and Simulation	3	0	0	3
CHX-4XX	Departmental Elective I	3	0	0	3	CHX-404	Industrial Safety & Hazards Management	3	1	0	4
CHX-4XX	Departmental Elective II	3	0	0	3	CHX-4XX	Departmental Elective III	3	0	0	3
OE-4XX	Open Elective I	3	0	0	3	CHX-4XX	Departmental Elective IV	3	0	0	3
CHX-403	Process Plant Design	1	0	2	2	OE-4XX	Open Elective II	3	0	0	3
CHX-421	Chemical Engineering Computing	0	0	3	2	CHX-422	Modeling and Simulation Lab	0	0	3	2
CHX-423	Project Phase I	0	0	4	2	CHX-424	Project Phase II	0	0	8	4
CHX-425	Industrial Practical Training	0	0	0	4						
	Total	**13**	**1**	**9**	**23**		**Total**	**15**	**1**	**11**	**22**
Credits (III to VIII Semester)								**144**			
Total Credits (I to VIII Semester)								**190**			

Departmental Electives I and II			**Departmental Electives III and IV**	
CHX-451	Allied Chemical Technology		CHX-452	Computational Fluid Dynamics
CHX-453	Biochemical Engineering		CHX-454	Energy Management and Audit
CHX-455	Environment Impact Assessment		CHX-456	Industrial Environmental Management
CHX-457	Industrial Rheology		CHX-458	Introduction to Multiphase Flow
CHX-459	Membrane Separation Processes		CHX-460	Instrumental Methods of Analysis
CHX-461	Optimization Techniques		CHX-462	Natural Gas Engineering
CHX-463	Petroleum Recovery Technology		CHX-464	New and Renewable Energy Resources
CHX-465	Petroleum Refining Technology		CHX-466	Petrochemical Technology
CHX-467	Polymer Science and Engineering		CHX-468	Process Plant Utilities

Open Electives I and II	
CHX-471	Environmental Engineering
CHX-472	Hydrocarbon Engineering
CHX-473	Industrial Safety & Hazards Management
CHX-474	New and Renewable Energy Resources
CHX-475	Polymer Science and Engineering
CHX-476	Oil and Natural Gas Economics

B. Tech. Chemical Engineering III Semester

Course Code	Course Title	L	T	P
MAX-201	Mathematics II	3	1	0

Heading 1

Heading 2

Heading 3

Recommended Books

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Course Code	Course Title	L	T	P
CSX-207	Object Oriented Programming	3	0	0

Heading 1

Heading 2

Heading 3

Recommended Books

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Course Code	Course Title	L	T	P
CHX-201	Fluid Mechanics	3	1	0

Introduction

Introduction, Ideal and real fluids, Extensive and Intensive Properties, Specific Weight, Mass density and Specific gravity, Viscosity, Surface Tension and Capillarity, Evaporability and Vapour pressure, Newtonian & Non Newtonian fluids.

Fluids Static

Pressure, Hydrostatics law, Pascal's Law, Different types of manometer, Continuous gravity Decanter, Centrifugal decanter and other pre- measuring equipments, Determination of meta centric height.

Fluids Kinematics and Dynamics

Classification of fluid flows, streamline, streak line, and Path lines, Flow rate & continuity equation, Bernoulli's Theorem, Kinetic energy correction factor and momentum correction factor in Bernoulli's equation.

Laminar Viscous Flow and Flow measurement devices

Flow regimes and Reynolds numbers, Laminar flow in circular pipes (Hagen Poiseuille Law), Venturimeter, Orifice Meter.

Hydraulic pumps

Pump Classification & Applications, Centrifugal pumps verses Reciprocating pumps, pump losses and Efficiencies, Multistage pumps, Work and power Input, Cavitation and maximum Suction lift, specific and minimum speed.

Flow around Immersed Bodies

Drag force, lift and drag coefficients, drag on Flat Plate, Circular Cylinder and Sphere.

Recommended Books

1 Smith J. C., McCabe W. L., Harriot P. H., "Unit Operations of Chemical Engineering", McGraw Hill (2001).

2 Kumar D. S., "Fluid Mechanics & Fluid pwer engineering", S. K. Kataria & Sons, (2004).

3 Timoshenko S. P. and Young D. H., "Engineering Mechanics", McGraw Hill, (1937).

4 Perry's, "Handbook of Chemical Engineering", 7th Edition, McGraw Hill, (1997).

Course Code	Course Title	L	T	P
CHX-203	Mechanical Operations	3	1	0

Size Reduction

Particle size and shape, particle mass, size and shape distributions, measurement and analysis, concept of average diameter, size reduction, crushing, grinding and law of grindings.

Screening
Screening equipment, capacity and effectiveness of screen, effect of mesh size on capacity of screen.

Settling
Flow around a single particle, drag force and drag coefficient, settling velocity of particles in a fluid, hindered and free settling of particles, thickening gravity separation.

Filtration
Classification of filters, various types of cake filters, principle of cake filtration, clarification filters, liquid clarification, centrifugal settling process.

Agitation & Mixing
Agitation of liquids, axial flow impellers, radial flow impellers, velocity and power consumption of agitated vessels, blending & mixing.

Fluidization
Packed beds, bed porosity, flow though a bed of particles, fluidization & fluidized bed, conditions for fluidization minimum velocity, types of fluidization.

Solid Handling
Flow of solid by gravity, transport of solids by screw/ belt conveyers, cyclones, bag filters, electrostatic precipitators, particulate collection system.

Recommended Books

1 Smith J. C., McCabe W. L., Harriot P. H., "Unit Operations of Chemical Engineering", McGraw Hill, (2001).

2 Brown G. G. "Unit Operations", 1st Edition, CBS Publisher, (2004).

3 Richardson and Coulson "Chemical Engineering Vol II", 5th Edition, Butterworth–Heinemann, (2002).

4 Perry's, "Handbook of Chemical Engineering", 7th Edition, McGraw Hill, (1997).

5 Bhattacharya B. C., Narayanan C. M., "Mechanical Operation for Chemical Engineers"

Course Code	Course Title	L	T	P
CHX-205	Chemical Process Calculations	3	1	0

Introduction to Chemical Engineering Calculations
Units and dimensions, mole concept, conventions in methods of analysis and measurement, basis, temperature, pressure, the chemical equations and stoichiometry, limiting and excess reactant, conversion and yield.

Material Balance
Material balance, program of analysis of material balance problems, solving material balance problems that do not involve chemical reactions, solving material balances problems involving chemical reactions, multiple subsystems, recycle, bypass, and purge calculations. Gases Vapors, Liquids and Solids: Ideal gas law calculations, real gas relationships, vapor pressure and liquids, saturation, partial saturation and humidity.

Energy Balance
Concepts and units, calculation of enthalpy changes, application of the general energy balance without reactions occurring energy balances that account for chemical reaction, reversible processes and the mechanical energy balances, heats of solution and mixing, psychometric charts and their use.

Recommended Books

1 Himmelblau D. M., "Basic Principles and Calculations in Chemical Engineering", Prentice Hall, (1998).

2 Haugen O. A., Watson K. M. Ragatz R. A., "Chemical Process Principles (Part-I): Material and Energy Balances", Asia Publishing House, (1995).
3 Bhatt B. I., Vora S. M., "Industrial Stoichiometry", Tata McGraw Hill Publishing, New Delhi, (1987).
4 Reklaitis G. V., "Introduction to Material and Energy Balances", Wiley, New York, (1983).
5 Felder R. M., Rousseau R. W., "Elementary principles of Chemical Processes", 2nd Edition, Wiley, New York, (1986).

Course Code	Course Title	L	T	P
CSX-227	Object Oriented Programming Lab	0	0	2

List of Experiments

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Course Code	Course Title	L	T	P
CHX-221	Fluid Mechanics Lab	0	0	3

List of Experiments

1. To find coefficient of friction in pipes of different materials.
2. To verify Bernaulli's equation using hydraulic bench.
3. To find losses due to sudden expansion and sudden contraction in pipes.
4. To calculate Reynold's number for laminar and turbulent flow.
5. To calculate metacentric height.
6. To determine volumetric and mass flow rates through the Venturi meter.
7. To determine volumetric and mass flow rates using Orifice meter.
8. To determine the efficiency of a pump.
9. To calibrate and to find mass flow rate through Rotameter.

Course Code	Course Title	L	T	P
CHX-223	Mechanical Operations Lab	0	0	3

List of Experiments

1. Determination of power consumption and study of agitation and mixing characteristic of a fluid.
2. Determination of drag coefficient from the plot of drag coefficient Vs modified Reynolds no.
3. To determine pressure drop through a packed bed: To plot the graph between modified Reynolds no. vs. modified friction factor and verify Ergun Equation in packed column.
4. To find out the collection efficiency of a cyclone separator.
5. Determination of screening efficiency in a vibrating screen.

6. Plate and frame filter press: determination of cake resistance and filter medium resistance.
7. Determination of specific cake resistance in constant pressure vacuum filtrations.
8. To study filtration characteristics of a leaf filter.
9. To study the flow through a helical coil.
10. To study the crushing efficiency of a roll crusher.
11. To study flow through an orifice.
12. To study the settling characteristics in a batch settling experiment and use the data to design a thickener for the given flow rate.

Course Code	Course Title	L	T	P
MAX-202	Mathematics III	3	1	0

Heading 1

Heading 2

Heading 3

Recommended Books

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Course Code	Course Title	L	T	P
PHX-204	Material Science and Engineering	3	1	0

Structure of Crystalline Solids

Crystal structures and crystal system, reciprocal lattice, miller indices, closed packed structures, determination of crystal structures.

Imperfection in Solid

Point imperfections and their equilibrium concentration, Edge and screw dislocations; burgers vector and the dislocations; burgers vector and the dislocation leap, stress fields and energies of dislocations, dislocations forces, dislocation sources; Multiplication of dislocations.

Diffusion in Solids

Fick's laws of diffusion, solution to fick's second law, applications based on second law solution, the kirkendall effect, the atomic model of diffusion.

Mechanical Properties

The elastic properties, model of elastic behaviour, plastic deformation tensile stress-strain curve, shear strength of perfect and real crystals, mechanical failure, fatigue and fracture, creeps: mechanism of creep, characterization of creep curves.

Electrical Properties

Classical and quantum theory of free electronics; relaxation time, collision time and mean free path, density of

energy states and Fermi energy, electron motion under periodic potential, origin of energy bands in solids, classification of material on the basis of band gap, effective mass, intrinsic and extrinsic semi-conductors, hall effect and its applications.

Dielectric Properties
Mechanism of polarization concept of polarizability and internal fields, dielectrics in alternating field; frequency dependence of polarizability.

Magnetic Properties
Magnetic moments and its origin, dia-and para-magnetism, ferro and ferri-magnetism, soft and hard magnetic materials, ferrites, application of magnetic materials.

Super conductivity
Properties of superconductors. London equations, quantum explanation of super conductivity, flux quantization, application of super conductors.

Recommended Books

1 Calister W. D., Jr. "Materials Science and Engineering", John Wiley and Sons, Inc. New York, (1997).

2 Dekker A. J., "Solid State Physics", Macmillan, India Limited, Madras, (1991).

3 Azaroff L. V., "Introduction to Solid", Tata Mc Graw Hill, New Delhi, (1992).

4 Raghvan V., "Material Science and Engineering", Prentice Hall of India, New Delhi, (1998).

5 Kittal, "Solid State Physics", Wiley Eastern Limited, New Delhi, (1987).

Course Code	Course Title	L	T	P
CHX-202	Chemical Technology	3	1	0

Soaps and Detergents
Raw materials and Reaction Chemistry, Continuous process for manufacture of fatty acids, soaps and glycerine, Classification of detergents, Builders and additives, Manufacture of detergents like alkyl benzene sulphonate, Sodium alkane sulphonate.

Fertilizers
Status of industry, grading and classification of fertilizers, raw materials, hydrogen production, and synthesis of ammonia based fertilizers, manufacture of phosphatic fertilizers and phosphoric acid, potash fertilizers, N-P-K values. Corrosion problems and materials of construction.

Chlor Alkali Industry
Electrochemistry of brine electrolysis, current efficiency, energy efficiency, diaphragm cells, mercury cells, mercury pollution and control, membrane cells, caustic soda, chlorine, hydrochloric acid; corrosion problems and materials of construction.

Cement
Raw materials, Types of cement, Properties of cement, Manufacture of cement.

Glass
Types of glass, Raw materials and manufacture of glass.

Soda Ash

Manufacturing, solvay and modified solvay process, materials of construction environmental considerations and corrosion problems.

Recommended Books

1 Dryden C. E., "Outlines of Chemical Technology", 2nd Edition, East–West Press Pvt. Ltd., New Delhi, (1973).

2 Austin G. T., "Shreve's Chemical Process Industries", 5th Edition, McGraw Hill Book Company, New Delhi, (1986).

3 Chemical Engineering Education Development Centre "Chemical Technology I, II, III, IV, Manual of Chemical Technology, Indian Institute of Technology, Madras".

4 Shukla S. D., Pandey G. N., "A text book of Chemical Technology, Vol. I", Vikas Publishing House Pvt. Ltd., New Delhi.

5 Shukla S. D., Pandey G. N., "A text book of Chemical Technology, Vol. II", Vikas Publishing House Pvt. Ltd., New Delhi.

Course Code	Course Title	L	T	P
CHX-204	Chemical Engineering Thermodynamics	3	1	0

Review of First , Second and Third Law of Thermodynamics

First law of Thermodynamics , Thermodynamics state and state functions, enthalpy, the steady state steady flow process, equilibrium, phase rule, reversible processes, Second law of thermodynamics, Heat engines, Entropy, Entropy changes of an ideal gas, Third law of thermodynamics.

Volumetric properties of pure fluids

PVT behaviour for an ideal gas, Virial equation of state, Applications of Virial equations, Cubic equation of state, Generalized correlations, Acentric factor.

Heat Effects

Sensible Heat Effects, Internal Energy of ideal gases, Latent heat of pure substances, Standard heat of reaction, formation, combustion, Heat of reaction at higher temperature, Heat effects of Industrial reactions.

Thermodynamic Properties of the fluid

Maxwell relations, Residual properties, two phase system, Thermodynamic diagram

Equilibrium and Stability

Criteria of equilibrium, Chemical Potential, Application of equilibrium criteria, Clausius clapeyon equation.

Phase Equilibria

Fugacity, Determining of fugacity of pure substances, Fugacity in mixture, Ideal solution, Excess properties, and Liquid phase properties from VLE data, Activity coefficients, and coefficient equations.

Chemical Reaction Equilibria

Reaction ordinate for single & multiple reactions , condition of equilibrium for a chemical reactions, Standard states and G, Temperature dependence of the equilibrium constant, Estimation of equilibrium rate constant, Homogeneous gas phase reactions, Heterogeneous chemical equilibrium.

Recommended Books

1 Smith J. M., Van Ness H. C., Abbott M. M., "Introduction to Chemical Engineering Thermodynamics", 6th Edition, Tata McGraw Hill, (2003).

2 Rao Y. V. C., "Chemical Engineering Thermodynamics", First Edition, Universities Press (India) Ltd., Hyderabad, (1997).

3 Kyle B. G., "Chemical and Process Thermodynamics", Third Edition, Prentice Hall Inc., (1999).

4 Denbigh K. G., "Principles of Chemical Equilibrium", 4th Edition, Cambridge University Press, (1981).

5 Halder G., "Introduction to Chemical Engineering Thermodynamics", Prentice Hall Inc., (2009).

Course Code	Course Title	L	T	P
CHX-206	Heat Transfer Operations	3	1	0

Conduction

Basic law of heat conduction-Fourier's law, thermal conductivity, its dependence on temperature, steady state heat conduction through a composite solid and its electric analogue, steady state heat conduction through cylinders, spheres and variable area of solids, different insulating materials and their applications for process equipment and pipelines, Fourier's law in three dimensions, lumped capacity method of unsteady state conduction.

Convection

Convection heat transfer and the concept of heat transfer coefficient, individual and overall heat transfer coefficient, heat transfer between fluids separated by plane wall, heat transfer between fluids separated by cylindrical wall (pipes), critical/ optimum insulation thickness, heat transfer through extended surfaces.

Forced Convection and Free Convection

Over a flat plate, thermal boundary layer, dimensionless groups and dimensional analysis, Buckingham Pi-theorem, heat transfer correlations- internal and external flows, laminar and turbulent flows. Heat transfer correlations for free convection, free convection from flat surfaces, free convection from a cylinder.

Heat Transfer with phase change

Boiling phenomena and analysis of boiling curve, correlation for nucleate boiling, critical heat flux, condensation phenomena, film condensation on a vertical surface (Nusselt equation, effect of non-condensable gases, drop wise condensation.

Radiation

Basic principle of radiation from a surface, blackbody radiation, Planck's law, Wien's displacement law, the Stefan Boltzmann law, Kirchhoff's law, gray body, radiation exchange between black bodies & gray bodies.

Evaporation

Types of evaporators, single and multiple effect evaporators, capacity and economy, boiling point elevation.

Recommended Books

1 Dutta B. K., "Heat Transfer: Principles and Applications", Prentice Hall of India Limited, (2004).

2 Holman J. P., "Heat Transfer", McGraw Hill Book Co., (1992).

3 Geankopolis C. J., "Transport Processes and Separation Process Principles", Prentice Hall of India, 4th Edition, Eastern Economy Edition, (2004).

4 Kern D. Q., "Process Heat Transfer", McGraw Hill Book Co., (1997).

5 Coulson J. M., Richardson J. F., "Chemical Engineering" Volume 1, Pergamon Press, (1999).

Course Code	Course Title	L	T	P
PHX-214	Material Science and Engineering Lab	0	0	2

List of Experiments

1. To determine the magnetic susceptibility of a paramagnetic salt by Guoy's balance method.

2. To calibrate an electromagnet.
3. To determine the resistivity of a semiconductor by four-probe method.
4. To estimate the band gap energy of a semiconductor using four probe method.
5. To find Young's modulus, modulus of rigidity and Poisson's ratio for the material of a given wire by Searle's method.
6. To find the coefficient of thermal conductivity of bad conductor by Lee's disc method.
7. To determine the Hall coefficient of a semiconductor and hence to estimate the charge carrier concentration.
8. To investigate creep of a copper wire at room temperature.

Course Code	Course Title	L	T	P
CHX-222	**Chemical Technology Lab**	**0**	**0**	**3**

List of Experiments

11. To determine the acid value of a vegetable oil and lubricating oil
12. To determine the saponification value of vegetable oil
13. To estimate the given reducing sugar
14. To estimate the given non reducing sugar
15. To study loss on Heating of Tar and Bitumen
16. To analyze the given cement sample
17. To determine the viscosity of a given sample by Redwood Apparatus
18. To standardize the given Fehling's solution
19. To study the given polymerization reaction
20. To determine the viscosity of a given sample by U-tube viscometer

Course Code	Course Title	L	T	P
CHX-224	**Heat Transfer Lab**	**0**	**0**	**3**

List of Experiments

1. Determination of emmissivity of the given test plate
2. Determination of thermal conductivity of the given liquid
3. Determination of thermal conductivity of insulating powder
4. Determination of heat transfer coefficient by forced convection
5. Determination of heat transfer coefficient for pin fin by natural convection
6. Determination of heat transfer coefficient for pin fin by forced convection
7. Determination of overall heat transfer for parallel flow in double pipe heat exchange
8. Determination of overall heat transfer coefficient for counter flow in double pipe heat exchanger
9. To conduct test on heat pipe and comparison of the temperature distribution
10. Determination of heat transfer coefficient in shell & tube heat exchanger
11. Determination of overall heat transfer coefficient in an open pan evaporator
12. Determination of heat transfer coefficient by dropwise and filmwise condensation

B. Tech. Chemical Engineering V Semester

Course Code	Course Title	L	T	P
CYX-301	Nano Science and Nano Technology	3	1	0

Heading 1

Heading 2

Heading 3

Recommended Books

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Course Code	Course Title	L	T	P
CHX-301	Mass Transfer Operations I	3	1	0

Mass Transfer Operations

Classification of mass transfer operation, choice of separation methods. Diffusion in Mass Transfer: Steady state molecular diffusion in fluids at rest and in laminar flow, molecular diffusion in gases, molecular diffusion in liquids, diffusivity in liquids and gases, momentum and heat transfer in laminar flow.

Mass Transfer Coefficient

Local and overall mass transfer coefficient, heat and mass transfer analogy, eddy diffusivities, film theory, penetration theory, surface renewal theories, combination film theory and surface stretch theory.

Inter phase Mass Transfer

Equilibrium, local two phase mass transfer coefficients, Local overall Mass Transfer coefficients, material balance for co current & counter current processes, cascades and concept of Ideal stage and stage efficiencies, continuous contact equipments.

Gas Absorption

Choice of solvent, Estimation of number of ideal stages – Graphical and Analytical methods, Minimum solvent flow rate, Significance of absorption factor, number of transfer units and height of a transfer unit (NTU & HTU) concepts, packed column for absorption, rate of absorption, height of column based on condition in gas film and liquid film, height based on overall coefficients, equipment for gas absorption.

Drying

Equilibrium in drying, batch drying and rate of batch drying, time of drying, Through circulations drying & continuous drying, batch & continuous drying equipments.

Recommended Books

1 Geankopolis C. J., "Transport Processes and Separation Process Principles", Prentice Hall of India, 4th Edition, Eastern Economy Edition, (2004).

2 Treybal R. E., "Mass Transfer Operations" 3rd Edition, McGraw Hill, (1980).

3 McCabe W. L., Smith J. C. "Unit Operations of Chemical Engineering", McGraw Hill, (2001).

4 Coulson J. M., Richardson J. F., "Chemical Engineering, Vol. 2", McGraw Hill, (1999).

5 Walter L., Badger, Julius T. B, "Introduction to Chemical Engineering", McGraw Hill, (1997).

Course Code	Course Title	L	T	P
CHX-303	Chemical Reaction Engineering I	3	1	0

Introduction

Kinetics of homogeneous chemical and biochemical reactions, single and multiple reactions, order & molecularity, rate constant, elementary and non elementary reactions, temperature dependent term of rate equation.

Interpretation of Batch Reactor

Constant volume batch reactor, integral method of analysis of data, series and parallel reactions, reversible reactions, Variable volume batch reactor, Differential methods of analysis, Temperature and reactions rate.

Introduction to Reactor Design

Ideal batch reactor, mixed flow reactor, plug flow reactor, holding and space time, design for single reactions, size comparison (analytical and graphical method, plug flow reactors in series & parallel, mixed reactor in series, recycle reactors.

Design for Multiple Reactions

Reactions in parallel and series in CSTR, reactions in parallel and series in Plug flow reactor, yield & selectivity.

Temperature and Pressure Effects

General design procedure, optimum temperature progression, adiabatic operation, non adiabatic operation, semi batch reactors.

Non Catalytic Fluid Solid Reactions

Selection of model, unreacted core model for spherical particles, diffusion through gas film control, diffusion through ash layer control, chemical reaction control, Design.

Recommended Books

1 Levenspiel O., "Chemical Reaction Engineering", 1999, 3rd Edition, John Wiley & Sons, Singapore.

2 Fogler H. S., "Elements of Chemical Reaction Engineering", 1999, 3rd Edition, Prentice Hall Inc.

3 Smith J. M., "Chemical Engineering Kinetics", 3rd Edition, McGraw Hill, (1981).

4 Hill C. G., "Chemical Engineering Kinetics and Reactor Design", John Wiley, (1977).

5 Coulson J. M., Richardson J. F., "Chemical Engineering Volume 3", Pergamon Press, (1999).

Course Code	Course Title	L	T	P
CHX-305	Hydrocarbon Engineering	3	1	0

Scope and Purpose of Refining

Global and Indian refining scenario, Petroleum refining industry in India practice and prospects, Separation and Conversion processes etc.

Refinery Distillation Processes

Desalting, Process description of typical crude distillation, Fractional distillation, Vacuum distillation, Flooding, Weeping, Entrainment, Setting of cut point, Crude assay analysis, ASTM, TBP EFV Distillation etc.

Fuel Refining and Lube Refining

Cracking, Coking, Reforming, Alkylation, Isomerisation, Polymerization, and Sweetening etc. Solvent extraction, Dew axing, Propane deasphalting etc.

Hydro processing

Hydro cracking, Hydro treating, Hydro desulphurization

Oil and Gas separators

Principal of separation, Types of separators, their description. Various control and vessel internals, Oil and gas gravitational separator, Vertical two and three phase separator, Horizontal three phase separator etc.

Quality Monitoring of Petroleum Products

API gravity, Flash point, Fire point, Smoke point, Aniline point, Carbon residue, Kinetic viscosity, Pour point, Freezing point, octane number, Cetane number, Viscosity index, Diesel index, Calorific value, Burning test 24 hours, Characterization factor, Cloud Point, Vapour lock index, Carbon hydrogen ratio, Calculated ignition index, Carbon aromaticity index, U.O.P Characterization factor, Conrad son carbon residue, Water and sediment content.

Storage of Petroleum Products

Classification of inflammable liquids, Classification of storage tank, Floating roof tank, Fixed roof tank, Semi buried tank, Import/export loss, Breathing losses, Hazards and non-hazards area, and underground storage tank etc.

Transportation

Transportation of oil and natural gas by rail, road and pipeline, Various type of pipelines, Pipe line automation, Lease Automatic Custody Transfer units, SCADA, Batch transport of petroleum products, Multiproduct pipelines, Product handling, Pumping cycle, Interface , Problems in waxy crude, Role of flow behaviour etc.

Marketing of Petroleum and Petroleum products

Role of International oil companies and OPEC pricing mechanism, Administered and market determined pricing mechanism in India.

Natural gas

Structural analysis of gas industry, Types of natural gas, Units of natural gas, Impurities of natural gas, Natural gas quality, LNG Scenario in India etc.

Recommended Books

1 Nelson W. L., "Petroleum Refinery Engineering", Mc Graw Hill Book Co. ,(1985).

2 Watkins R. N., "Petroleum Refinery Distillation", Gulf Publishing Co.

3 Gary J. H., Handwork G. E., "Petroleum Refining Technology and Economics", Marcel Dekker, Inc., (2001).

4 Jones D. S. J., "Elements of Petroleum processing", John Wiley & Sons, (1995).

5 Waquier J. P., "Petroleum Refining" Vol. I & II , Technip, (1995)

Course Code	Course Title	L	T	P
CHX-307	Energy Technology	3	1	0

Solid Fuels
Principle Solid Fuels–Coal, origin, composition & classification of coal, Properties of coal, terms used in analysis of coal, classification of Indian coals, petrology of coal

Coal Preparation
Dry and Wet processes, storage of coal. Coal carbonisation: mechanism of carbonisation, high temperature and low temperature carbonization briquetting, gasification of coal, Lurgi process, Winkler process, Kopper–Totzek process, liquefaction of solid fuels.

Liquid Fuels
Petroleum and related products, origin, occurrence and reserves, nature of petroleum crudes, classification and characteristics of petroleum, Refining Unit Process: Cracking, Thermal Cracking, Catalytic cracking, Hydrocracking, Reforming Thermal and Catalytic Reforming, Alkylation, Polymerization Isomerization, petroleum products: naphtha, motor gasoline, aviation gasoline, kerosene, diesel oil, gas oil, fuel oil, lubricants, petroleum waxes, petroleum coke.

Gaseous Fuels
Classification, Wobbe Index natural gas, methane from coal mines, producer, water, carburetted water gas, coal, blast furnace, refinery gases, LPG.

Combustion
General Principles of combustion, stoichiometry & heat balance calculations, coal burning equipments, stokers, pulverized fuel burners gas and oil burners, fluidized bed combustion.

Alternate Energy Systems
Solar Energy–Photovoltaic cells, solar collectors. Nuclear energy: nuclear reactions, fuel materials, moderators and structural materials, reactors, wind energy, tidal energy, and geothermal energy.

Furnaces
General classification and description of different types of furnaces

Recommended Books

1 Brame J. S., King J. C., "Fuels-Solid, Liquid and Gaseous", St. Martin Press.

2 Sarkar S., "Fuels and combustion", Longman publishers India Ltd., 2nd Edition.

3 Haslam R. T., Russel R. P., "Fuels and their combustion", McGraw Hill.

4 Gupta O. P., "Elements of Fuels, Furnaces and Refractories", Khanna Publishers.

5 Griswold J., "Fuels combustion and furnaces", McGraw Hill.

Course Code	Course Title	L	T	P
CHX-321	Process Equipment Design	1	0	2

Introduction
Introduction to principles involved in the design and construction of plant.

Design preliminaries
Design codes, pressure, temperature, factor of safety, corrosion allowance, weld joint efficiency factor, design loadings, Poisson's ratio, dilation of pressure vessels, criteria of failure, material of construction.

Storage tanks
Introduction to Indian standards for storage tanks and their use to design cylindrical and spherical vessels under internal pressure, fixed roof and open roof tanks.

Mechanical design
Mechanical design of tall vessels for distillation and absorption columns.

Design of supports
Design of supports for vertical and horizontal vessels, Flanges.

Recommended Books

1 Bhattacharya B. C., "Chemical Equipment Design", CBS Publisher, (1985).

2 Sinnott R. K., Coulson & Richardson, "Chemical Engineering, Vol.6", 2nd Edition, Butterworth Heinemann, Oxford, (1998).

3 Ludwig E. E., "Applied Process Design for Chemical and Petrochemical Plants, Vol. 1, 2 and 3", 3rd Edition, Gulf Publishing Company, Houston, (1995).

4 Perry's, "Handbook of Chemical Engineering", 7th Edition, McGraw Hill, (1997).

5 Ulrich G. D., "A Guide to Chemical Engineering Process Design and Economics", John Wiley, (1984).

Course Code	Course Title	L	T	P
CHX-323	Energy Technology Lab	0	0	3

List of Experiments

1. To determine the flash point of a given sample
2. To determine the Smoke Point of a given sample
3. To study the Distillation of Petroleum Products
4. To determine the calorific value of a fuel using Peroxide Bomb Calorimeter
5. To estimate the moisture content in the given coal sample
6. To determine the Cloud Point and Pour Point of a given sample
7. To study the burning properties of the given sample
8. To determine the Melting Point of Petroleum wax

Course Code	Course Title	L	T	P
CHX-302	Instrumentation and Process Control	3	1	0

General principles of measurement

Static and dynamic characteristics of instruments, Temperature Measurement: Thermocouples, resistance thermometers, thermistors, optical and radiation pyrometers. Pressure Measurement: Use of manometers, Bourdon gauge, bellows type gauge, measurement of vacuum and pressure transducers. Flow Measurement: Variable area meters. Pressure probes, positive displacement type meters. Liquid level Measurement: Direct and differential method, measurement in open and pressure vessels, measurement of liquid.

Process control

Laplace Transform: Transforms of simple function, Transforms of Derivative, Initial value theorem and Final value theorem, Transform of Integral

Response of First order systems and higher order systems

Mercury thermometer & its transfer function, Forcing functions, Liquid Level System, Liquid Level Process with constant flow out let, Linearization, Mixing tank & R.C. Circuit**,** Response of First order system in series: Non interacting System and Interacting Systems. Transfer function of second order system, under damped System, Impulse function, Sinusoidal function, Transportation lag

Controllers and final control element

Control Valve, Proportional controller, Integral & Derivative controller, Comparison of P, PI and PID controllers.

Transient response of control system

Components of control system, block diagram, Negative and Positive feedback, Servo problem and Regulation Problem, Development of Block diagram. Proportional control for set point change, Proportional control for load change, Proportional Integral control for load change, Proportional Integral Control for set point change

Stability of the system

Concept of stability, Stability Criteria, Routh test for stability. Introduction to frequency response: Bode diagram for first order, Bode diagram for proportional, Integral and derivative control, Second order system. Control System Design by frequency response: Bode stability criteria, Gain and phase Margin, Ziegler Nichols Controller settings.

Recommended Books

1 Coughanower D. R., "Process System Analysis and Control", 1991, 2nd Edition, McGraw Hill.

2 Seborg, E., Mellichamp, "Process Dynamics & Control", 2nd Edition, John Wiley, (2004).

3 Stephanopoulos, "Chemical Process Control-An Introduction To Theory & Practice", 1st Edition, Prentice Hall Inc.

4 Eckman D. P., "Industrial Instrumentation", Wiley Eastern Ltd., (1975).

5 Kerk F. W., Rimboi W., Tarapore R., "Instrumentation", Wiley and Sons, (1983).

Course Code	Course Title	L	T	P
CHX-304	Mass Transfer Operations II	3	1	0

Distillation

Mass Transfer equilibria for vapour-liquid, liquid-liquid, solid-liquid and solid-gas systems, Raoult's Law and Dalton's law, partial vaporisation and partial condensation, relative volatility, differential distillation & flash distillation, steam distillation, Lewis Sorel and McCabe–Thiele methods & numerical, Ponchon Savarit method,

Underwood and Fenske equations, total reflux , minimum and optimum reflux ratios, multiple feeds and side streams.

Liquid-Liquid Extraction
Ternary phase diagrams & choice of solvent, single stage and multistage cross current, co-current and counter current extraction operation for immiscible and miscible solvents, related numerical problems, continuous contact extractors.

Leaching
Mass transfer in leaching, equipment for leaching, single stage and multistage cross current, co-current and counter current leaching operations, related numerical problems.

Adsorption
Introduction and the nature of adsorbent, adsorption equilibria, the Langmuir isotherm, BET isotherm and Gibbs isotherm, potential theory and adsorption equipment.

Crystallization
Formation of nuclei, nuclei growth and properties of crystals, effect of impurities on crystals formation, effect of temperature on solubility, caking of crystals, yield of crystals, crystallisers, related numerical problems.

Recommended Books

1 Geankopolis C. J., "Transport Processes and Separation Process Principles", Prentice Hall of India, 4th Edition, Eastern Economy Edition, (2004).
2 Treybal R. E., "Mass Transfer Operations" 3rd Edition, McGraw Hill, (1980).
3 McCabe W. L., Smith J. C. "Unit Operations of Chemical Engineering", McGraw Hill, (2001).
4 Coulson J. M., Richardson J. F. "Chemical Engineering, Vol. 2", McGraw Hill, (1999).
5 Walter L, Badger, Julius T., "Introduction to Chemical Engineering", McGraw Hill, (1997).

Course Code	Course Title	L	T	P
CHX-306	Chemical Reaction Engineering II	3	1	0

Non Ideal Flow
Non ideal flow patterns, E, F & C Curve, Mean residence time, Models for non ideal flow, N Tanks in series model, conversion in a reactor using RTD data.

Heterogeneous Processes
Global rates of reaction, Types of Heterogeneous reactions Catalysis, The nature of catalytic reactions, Mechanism of catalytic reactions. Physical Adsorption and Chemisorption, Adsorption isotherms, Rates of adsorption isotherm.

Solid Catalysts
Determination of surface area, Void volume and solid density, Pore volume distribution, Theories of heterogeneous catalysis, Classification of catalysts, catalyst preparation, Promoter and inhibitors, Catalysts Deactivation

Rate Equations for Fluid solid catalytic reactions
Rates of Adsorption, Surface reaction, Desorption, Rate limiting step, Power Law, Langmuir Hishelwood rate, Eley Rideal mechanism, Packed bed reactor and fluidized bed reactor, Numerical Problems

Intra Pellet Mass Transfer
Gaseous diffusion in single cylindrical pore, Different modes of diffusion: Bulk diffusion, Knudsen diffusion and surface diffusion, Diffusion in Liquids, Diffusion in Porous Catalyst, Concepts of effective thermal conductivity

and effective diffusivity, Effectiveness factors

Reactors
Fixed Bed Catalytic Reactor, Single and multibed adiabatic reactors, Multitubular fixed bed reactors

Introduction to Fluid-Fluid Reactions
Kinetic Regimes for Mass Transfer and Reaction, Film Conversion parameter, Clues to the kinetic Regime from solubility data, Clues to the Kinetic Regime from equipment, Applications to design

Recommended Books

1 Levenspiel O., "Chemical Reaction Engineering", 3rd Edition, John Wiley & Sons, Singapore, (1999).

2 Fogler H. S., "Elements of Chemical Reaction Engineering", 3rd Edition, Prentice Hall Inc., (1999)

3 Smith J. M., "Chemical Engineering Kinetics", 3rd Edition, McGraw Hill, (1981).

4 Hill C. G., "Chemical Engineering Kinetics and Reactor Design", John Wiley, (1977).

5 Coulson J. M., Richardson J. F., "Chemical Engineering, Volume 3", Pergamon Press, (1999).

Course Code	Course Title	L	T	P
CHX-308	**Environmental Engineering**	**3**	**1**	**0**

Air Pollution Control Engineering
Introduction, Definition, Sources, Characteristics and Perspective of Air Pollutants, Effects of Air Pollution on Biodiversity, Economic Effects of Air Pollution, Air Quality and Emission Standards, Engineering Systems of Control of Air Pollution by Equipment and by Process Changes.

Water Pollution Control Engineering
Introduction, Definition, Sources, Characteristics and Perspective of Water and Wastewater Pollutants, Effects of Water Pollution on Biodiversity, Economic Effects of Water Pollution, Water Quality and Emission Standards, Physical, Chemical and Biological Parameters, Engineering Systems of Control of Water and Wastewater Pollution by Primary, Secondary and Advance Treatment.

Solid Waste Management
Introduction, Definition, Sources, Characteristics and Perspective of Solid Waste, Generation, Separation, Handling, Storage and Transportation of Solid Waste, Chemical and Biological Treatment of Solid Waste.

Biomedical and Hazardous Waste Management
Introduction, Definition, Sources, Characteristics and Perspective of Biomedical and Hazardous Waste, Handling, Storage, Transportation of Biomedical and Hazardous Waste, Physical, Chemical and Biological Treatment of Biomedical and Hazardous Wastes.

Recommended Books

1 Rao M. N., Rao H. V. N., "Air Pollution", Tata McGraw Hill Publishing Company Ltd., (2005).

2 Peavy H. S., Rowe D. R., Tchobanoglous G., "Environmental Engineering", McGraw Hill Book Company, International Edition, (1985).

3 Metcalf and Eddy, Inc., "Wastewater Engineering-Treatment and Reuse", Tata McGraw Hill Publishing Company Ltd., Fourth Edition, (2004).

4 Rittmann B. E., McCarty P. L., "Environmental Biotechnology: Principles and Application", McGraw Hill International Editions, First Edition, (2001).

5 Kiely G., "Environmental Engineering", Tata McGraw Hill, Special Indian Edition, (2007).

Course Code	Course Title	L	T	P
CHX-310	Process Engineering and Economics	3	1	0

Cost Estimation

Factors affecting investment & production costs, Capital investments (Fixed and working capital), Types of capital cost estimates, Cost Indexes, Estimating equipment costs by scaling 6/10 Factor Rule, Purchase Equipment Installation , Insulation costs, Instrumentation & Control, Piping , Electrical Installation , Service facilities, Land, Engineering . & Supervision, Start–up expenses. Methods of Estimating Capital Investment, Estimation of total product cost, Different costs involved in the total product for a typical Chemical Process plant.

Interest and Investment Costs

Types of interest (simple & compound interest), Nominal & Effective Rates of interest, Continuous interest, Present worth & discounts, perpetuities, capitalized costs, Interest & Investment costs.

Taxes and Insurance

Types of taxes, Property taxes, excise taxes, income taxes, Types of Insurance & Legal Responsibility.

Depreciation

Purpose of Depreciation as cost, Types of Depreciation, Depletion, Service life., Salvage value, Present value, Methods of determining Depreciation, Straight-line method, Declining Balance Method, Sum of the years Digits method, Sinking Fund Method, Single Unit & Group Depreciation.

Profitability, Alternative Investments & Replacement

Profitability standards, Mathematical methods of profitability evaluation: Rate of return on investment, Discounted cash flow method, Net Present worth, Capitalised costs, pay out period. Determination of Acceptable investment, Alternatives when an investment must be made, Alternative analysis by method of return on incremental investment, Alternative analysis incorporating minimum return as a cost, Replacements.

Optimum Design

General procedure for Determining optimum conditions, Procedure with one variable, Procedure with Two or More variables, Break even chart for production schedule and its significance for optimum analysis. Examples of optimum design in a Chemical Process Plant.

Recommended Books

1 Peters M. S., Timmerhaus K. D., "Plant Design and Economics for Chemical Engineers", 2003, 4th Edition, McGraw Hill, New York.,

2 Ulrich G. D., "A Guide to Chemical Engineering Process Design and Economics", John Wiley, (1984).

3 Guthrie K. M., "Process Plant Estimation, Evaluation and Control", Craftsman Solano Beach, California, (1974).

4 Douglas, "Conceptual Design of Chemical Processes", McGraw Hill, (1998).

5 Valle Riestra , "Project Evaluation in Chemical Process Industries", McGraw Hill.

Course Code	Course Title	L	T	P
CHX-322	Mass Transfer Lab	0	0	3

List of Experiments

1. To plot the ternary phase diagram for acetic-acid–water Toluene.
2. To draw the tie line and to determine plait point for ternary system.
3. To determine the diffusivity of acetone in air.

4. To study the drying characteristics of the given wet material (Natural Convection).
5. To determine the Mass Transfer Coefficient for vaporization of naphthalene in air.
6. To verify Rayleigh's Equation for Batch distillation.
7. To find HETP and HTU for packed distillation column.
8. To purify turpentine oil having high boiling point using steam distillation.
9. To determine VLE data for methanol–water and to compare it with literature data.
10. To determine the mass transfer coefficient by carrying out liquid-liquid extraction in a packed column using acetic acid- toluene-water system.
11. To study the drying characteristics of the given wet material (forced convection).
12. To study the process of crystallization in an agitated batch crystallizer and to plot a graph between weight of crystals vs. temp.
13. To find out mass transfer coefficient in a drop wise liquid–liquid extraction.
14. To Study the Heat and Mass Balance in Cooling Tower.

Course Code	Course Title	L	T	P
CHX-324	**Reaction Engineering and Control Lab**	**0**	**0**	**3**

List of Experiments

1. Determination of rate constant for saponification reaction in a batch reactor
2. Determination of porosity and sphericity of the given catalyst.
3. RTD study in a Packed bed reactor
4. To study the adsorption of acetic acid on charcoal and prove the validity of Freundlich and Langmuir adsorption isotherm
5. To study the adsorption of oxalic acid on charcoal and prove the validity of Freundlich and Langmuir adsorption isotherm
6. Determination the time constant of a given Mercury Thermometer.
7. Determination of time constant in a liquid level tank
8. Determination of time constant in interacting and non-interacting tank
9. Determination of time constant in a heated tank
10. To study the effect of proportional controller in a liquid level tank
11. To study the effect of proportional Integral controller in a liquid level tank

Course Code	Course Title	L	T	P
CHX-326	**Environmental Engineering Lab**	**0**	**0**	**3**

List of Experiments

1. To determine the Total Solids of a given sample.
2. To find out Total Dissolved Solids of a given sample.
3. To find out Fixed and Volatile solids of the given sample.
4. To determine Acidity of the given sample.
5. To determine the Alkalinity of the given sample.
6. To determine the Total Hardness of the given sample.
7. To find out amount of Sulphates in a given sample.
8. To estimate the content of Chlorides in the given water sample
9. To find the quantity of the Dissolved Oxygen present in the given sample.
10. To determine the BOD of a given wastewater sample.
11. To determine the COD of a given wastewater sample.

B. Tech. Chemical Engineering VII Semester

Course Code	Course Title	L	T	P
CHX-401	Transport Phenomena	3	1	0

Summary of vector and tensor Notation

Vector operations from a geometrical view point. Vector operation from an analytical view point, the vector differential operations, second order tensors, vector and tensor components in curvilinear coordinates, and differential operations in curvilinear coordinates.

Momentum Transport

Viscosity and the mechanism of momentum transport, Newton's law of viscosity, non- Newtonian fluids, pressure and temperature dependence of viscosity, theory of viscosity of gases at low density, theory of viscosity of liquids.

Velocity Distributions in Laminar Flow

Shell momentum balances: boundary conditions, flow of a falling film, flow through a circular tube, flow through an annulus, adjacent flow of two immiscible fluids.

The Equations of Change for Isothermal Systems

To equation of continuity, the equation of motion, the equation of mechanical energy.

Thermal Conductivity and the Mechanism of Energy Transport

Fourier's Law of heat conduction, temperature and pressure dependence of thermal conductivity in gases and liquids, theory of thermal conductivity of gases at low density, theory of thermal conductivity of liquids, thermal conductivity of solids.

Temperature Distributions in solids and in Laminar Flow

Shell energy balances; boundary conditions, heat conduction with an electrical heat source, heat conduction with a chemical heat source, heat conduction through composite walls: Addition of Resistance, Forced Convection, Free Convection.

The Equations of change for Non-isothermal systems

The equations of energy, the energy equation in curvilinear coordinates, the equations of motion for forced and free convection in nonisothermal flow, summary of the equations of change, use of equation of change to set up steady–state heat transfer problems.

Diffusivity and the Mechanism of Mass Transport

Definition of concentrations, velocities and mass fluxes, fick's law of diffusion, theory of ordinary diffusion in gases at low density, theory of ordinary diffusion in liquids.

Concentration Distributions in Solid and in Laminar Flow

Shell mass balances: boundary conditions, diffusion through a stagnant gas film, diffusion with heterogeneous chemical reaction, diffusion with homogeneous chemical reaction, diffusion into a falling liquid film l forced–convection mass transfer, Analogies between Heat, mass and momentum and transfers.

Recommended Books

1 Bird R. B., Stewart W. E., Lightfort R. N., "Transport Phenomena", John Wiley and Sons, (2002).

2 Welty J. R., Wilson R. E., Wicks C. E., "Fundamentals of Momentum, Heat and Mass Transfer", 4th Edition, John Wiley and Sons (2001).

3 John C. S., "Momentum, Energy and Mass transfer in continua", McGraw Hill, Co., (1972).

4 Bennet C. U., Myers J. E., "Momentum, Heat and Mass Transfer" ,Tata McGraw Hill Publishing Co., (1975).

5 Robert S. B., Harry C. H., "Transport Phenomena a Unified approach", McGraw Hill Book Co., (1988).

Course Code	Course Title	L	T	P
CHX-403	Process Plant Design	1	0	2

Heat exchangers

Classification of shell and tube heat exchanger, material of construction, cleaning of heat exchangers, heat transfer fluid, agitated vessels, description of shell, tubes, bonnet and channel, pass partition plate, nozzle, baffles, tie rods, baffle spacers, flanges, gaskets and expansion joints. Design of heat exchangers: Energy balance, heat duty consideration and process design of double pipe and shell and tube heat exchangers.

Mass Transfer Equipments

Types of mass transfer equipment, packed and tray type towers.

Tray Hydraulics

Bubble cap columns, perforated plate columns and packed towers.

Process Design

Process design of tray and packed towers.

Recommended Books

1 Kern D. Q., "Process Heat Transfer", McGraw Hill, (2001).

2 Perry's, "Handbook of Chemical Engineering" McGraw Hill, 7th Edition, (1997).

3 Coulson J. M., Richardson R. E., "Chemical Engineering" Vol. 2 and 6, Pergamon Press, (1998).

4 Van Winkle M., "Distillation", 1st Edition, McGraw Hill Company, New York, (1967).

5 Ludwig E. E., "Applied Process Design for Chemical and Petrochemical Plants", Vol. 1, 2 and 3, 3rd Edition, Gulf Publishing Company, Houston, (1995).

Course Code	Course Title	L	T	P
CHX-421	Chemical Engineering Computing	0	0	3

List of Experiments

1. Estimation of Molar Volume and Compressibility Factor from Van Der Waals.
2. Estimation of Molar Volume and Compressibility Factor from Redlich-Kwong.
3. Fitting Polynomials and Correlation Equations to Vapor Pressure Data.
4. Fitting Parameters in the Monod Equation for a Batch Culture.
5. Estimation of Vapor Pressure Correlation by Clapeyron and Antoine Equations.
6. Gas Volume Calculations Using Various Equations of State.
7. Estimation of specific volume of a non-ideal gas following Van der Waals equation by solving non-linear equation using Newton Raphson Method.
8. Bubble Point Calculation for an Ideal Binary Mixture.
9. Dew Point Calculation for an Ideal Binary Mixture.
10. Estimation of Adiabatic Flame Temperature in Combustion.
11. Estimation of Antoine Equation Parameters Using Nonlinear Regression.
12. Calculations involving Flash Evaporation of an Ideal Multicomponent Mixture.
13. Solution of simultaneous material balance equations using Gauss Jordan elimination method.
14. To study the transient behaviour of Continuous stirred tank reactor.
15. Numerical integration over batch reactor to find time using Simpson's rule/ trapezoidal rule.

Course Code	Course Title	L	T	P
CHX-423	Project Phase I	0	0	4

Project

As a part of the B. Tech. curriculum, the students are required to do a research oriented B. Tech. project work in their final year. The aim of this project is to impart to students a flavour of design, innovation and research. Every student will be required to submit a project report in a typed form on a topic selected by the student, but specifically approved by the Department Faculty member, who will guide the student or on a topic to be assigned by one or more Department Faculty members.

The project work on the topic will consist of some investigational work or computer simulation or design problem or experimental set up of some development work or of prototype equipment. Every student will be orally examined on the topic incorporated in the project and in the related area of specialization.

Course Code	Course Title	L	T	P
CHX-425	Industrial Practical Training	0	0	0

Industrial Practical Training

As a requirement every student studying for Bachelor's Degree in Technology has to undergo Industrial Practical Training for duration of six to eight weeks during May to July after completion of VI semester in any reputed industry or CSIR Laboratory or any Institute of National Importance including National Institute of Technology, Jalandhar etc. as approved by the Department. The training is aimed at giving students exposure to the profession in the real world of work as well as provide them with opportunities to correlate their theoretical understanding and the reality of the profession. The main objective of Industrial Practical Training is to promote the development of appropriate technology that meets national, regional and international needs through skills and practical oriented training, research and consultancy.

At the beginning of the next academic year, each student is supposed to hand in a report on the activities during the training and to make an oral presentation about it. The report should contain the following elements as per the guidelines of the Centre of Training and Placement of the Institute:

- Title of the work, name of the company with the full address and e-mail
- A short description of the company
- A description of the important parts of the work during the training
- Conclusions of the work

Based on this report and presentation, the Department Faculty will evaluate the training work of each student.

Course Code	Course Title	L	T	P
CHX-402	Modeling and Simulation	3	0	0

Introduction
Definition of mathematical model, lumped parameter models, distributed parameter models, uses of mathematical models, scope of coverage, principles of formulation.

Fundamental laws
Continuity equations, energy equations, equation of motion, equations of state, equilibrium, chemical kinetics

Mathematical Models for Chemical Engineering Systems
Series of isothermal constant holdup CSTRs, CSTRs with variable holdups, Two heated tanks, Non-isothermal CSTR, Single component vaporizer, Batch reactor, Ideal binary distillation column, Batch distillation with holdup, pH systems, Lumped parameter model of gas absorber, Model foe heat exchanger, Model for interacting & non-interacting tanks, Model for biochemical reaction.

Simulation
Meaning of simulation, Simulation examples of isothermal CSTR, non-isothermal CSTR, Batch reactor

Recommended Books
1 Luyben W. L., "Process Modeling Simulation and Control for Chemical Engineers", International Edition, McGraw Hill, (1990).
2 Rose L. M., "The Application of Mathematical Modelling to Process Development and Design", First Edition Applied Science Publisher Limited, London, (1974).
3 Bequette, "Process Dynamics- Modelling, Analysis and Simulation", PHI International, (2003).
4 Rase H. F., "Chemical Reactor Design for Process Plants, Vol II: Case Studies and Design Data", 1st Edition, John Wiley and Sons, New York, (1997).
5 Morton D. M., "Process Modelling", First Edition, Longman Publisher, (1986).

Course Code	Course Title	L	T	P
CHX-404	Industrial Safety & Hazards Management	3	1	0

Introduction
Concept of Loss prevention, acceptable risks, accident and loss statistics, nature of accident process, inherent safety.

Toxicology
Dose vs. response, toxicants entry route, models for dose and response curves, TLV and PEL

Industrial Hygiene
Identification, Material safety data sheets, Industrial hygiene evaluation, and control

Basics of Fires and Explosion
Fire triangle, definitions, flammability characteristics of liquid and vapours, LOC and inerting, types of explosions, Designs for fire prevention

Hazard identification
Hazard survey, checklist, HAZOP, safety reviews, what if analysis

Risk Assessment
Probability theory, event tree, fault tree, QRA and LOPA, Dow's fire and explosion index, Mond index, Dow's

Chemical release model

Accident Investigations and Case Histories

Bhopal gas tragedy, flixborough disaster, Pasadena accident, IOCL Jaipur fire

Recommended Books

1 Crowl D. A., Louvar J. F., "Chemical Process Safety Fundamentals with applications", (2002), 2nd Edition, Prentice Hall, NJ.

2 Coulson J. M., Richardson J. F., "Chemical Engineering", 2nd Edition, Vol 6, Pergamon Press, (1999).

3 Dow's Chemical Exposure Index Guide, Dow Chemical Company, New York, (1993).

4 Lees F P, Loss prevention in process Industries, 2nd Edition, Butterworth, London, (1996).

5 Wells G L, Safety in process Plant Design, George Godwin Ltd., New York, (1980).

Course Code	Course Title	L	T	P
CHX-422	**Modeling and Simulation Lab**	**0**	**0**	**3**

List of Experiments

1. Modeling and Simulation of Isothermal CSTR
2. Modeling and Simulation of non-isothermal CSTR
3. Modeling and Simulation of isothermal batch reactor
4. Modeling and Simulation of non-isothermal batch reactor
5. Modeling and Simulation of distillation column
6. Modeling and Simulation of heat exchanger
7. Modeling and Simulation of cyclone separator
8. Modeling and Simulation of CSTRs in series

Course Code	Course Title	L	T	P
CHX-424	**Project Phase II**	**0**	**0**	**8**

Project

As a part of the B. Tech. curriculum, the students are required to do a research oriented B. Tech. project work in their final year. The aim of this project is to impart to students a flavour of design, innovation and research. Every student will be required to submit a project report in a typed form on a topic selected by the student, but specifically approved by the Department Faculty member, who will guide the student or on a topic to be assigned by one or more Department Faculty members.

The project work on the topic will consist of some investigational work or computer simulation or design problem or experimental set up of some development work or of prototype equipment. Every student will be orally examined on the topic incorporated in the project and in the related area of specialization.

Course Code	Course Title	L	T	P
CHX-451	Allied Chemical Technology	3	0	0

Regenerated Cellulose
Growth of industry, raw materials, Pre-treatment, pulping, manufacture of paper, recovery of chemicals, environmental considerations, viscose rayon.

Cane sugar
Cane production and varieties, manufacturing equipment and technology, cane sugar refining, bagasse utilization, energy requirements and conservation, environmental considerations.

Polymers
Nomenclature of polymers and their classification, Modes of polymerization i.e. addition, condensation, step growth and chain growth polymerization, Methods of polymerization. Selected industrial polymerization, including plastics, synthetic fibers, synthetic and natural rubbers.

Agricultural Residue Utilization
Availability and Characteristics, energetic and energy contents, modes of energy recovery, gasification, pyrolysis, deoxygenation, chemicals from agricultural residues.

Sulphuric acid
Raw materials and manufacture of sulphuric acid

Oils and Fats
Status and scope: Major oil seeds production in India; expression, solvent extraction, energy and solvent requirements, minor oil seeds and other oil bearing materials, Hydrogenation of oils.

Recommended Books

1 Dryden C. E., "Outlines of Chemical Technology", 2nd Edition, East–West Press Pvt. Ltd., New Delhi, (1973).
2 Austin G. T., "Shreve's Chemical Process Industries", 5th Edition, McGraw Hill Book Company, New Delhi, (1986).
3 Chemical Engineering Education Development Centre "Chemical Technology I, II, III, IV, Manual of Chemical Technology, Indian Institute of Technology, Madras".
4 Shukla S. D., Pandey G. N., "A text book of Chemical Technology, Vol. I", Vikas Publishing House Pvt. Ltd., New Delhi.
5 Shukla S. D., Pandey G. N., "A text book of Chemical Technology, Vol. II", Vikas Publishing House Pvt. Ltd., New Delhi.

Course Code	Course Title	L	T	P
CHX-453	Biochemical Engineering	3	0	0

Introduction
Introduction to Biotechnology and Biochemical Engineering, An overview of basics of Biology.

Enzyme Kinetics
Enzyme kinetics, Immobilized enzyme systems, Industrial and Pharmaceutical applications of enzymes.

Cell Growth
Batch and Continuous growth, Quantifying cell concentration, growth patterns and kinetics.

Engineering Principles
Operating considerations for bioreactors for suspension and immobilized cultures, Modifying batch and continuous reactors. Selection, scale-up, operation and control of bioreactors.

Genetically Engineered Cells
Introduction to mutation, Natural mechanisms for gene transfer and rearrangement, Basic elements of genetic engineering, Genomics, Bioinformatics, Application of recombinant DNA technology.

Recommended Books

1 Bailey J. E., Ollis D. F., "Biochemical Engineering Fundamentals", McGraw Hill International Editions, Second Edition, (1986).
2 Shuler M. L., Kargi F., "Bioprocess Engineering", Prentice Hall of India Pvt. Ltd., Second Edition, (2005).
3 Primrose S. B., Twyman R. M., "Principles of Gene Manipulation and Genomics", Blackwell Publishing, Seventh Edition, (2006).
4 Dutta R., "Fundamentals of Biochemical Engineering", Springer Publications, (2010).
5 Najafpour G. D., "Biochemical Engineering and Biotechnology", Elsevier Publications, First Edition, (2007).

Course Code	Course Title	L	T	P
CHX-455	Environment Impact Assessment	3	0	0

Environment Impact Assessment (EIA)
Concept of EIA, Origin of EIA, Procedure of EIA, Evaluation Methodology for EIA, Scope Studies, Preparation and Review of Environment Impact Statement (EIS).

Life Cycle Assessment (LCA)
Introduction of LCA, Importance of LCA, Environmental Parameters in LCA, Documentation in LCA.

Waste Minimization
Introduction, Types of Waste, Benefits of Waste Minimization, Elements of Waste Minimization Programme, Integrated System for Waste Management.

Environmental Audit (EA)
Concept of EA, Necessity and Importance of EA, Audit Items, Audit Procedures.

Environmental Management System (EMS)
Introduction, Terminology and Certification, Environmental Standards, the International Standard Organization (ISO), the ISO 9000 and the ISO 14000 Family of Standards, Guides and Technical Reports, ISO 14001 Certification as a Tool for Sustainable Development

Case Studies
Discussion and analysis of various Case studies of environmental engineering projects.

Recommended Books

1 Anjaneyulu Y., "Environment Impact Assessment Methodologies", B S Publications, (2002).
2 Canter L. W., "Environment Impact Assessment", McGraw Hill, Second Edition, (2005).
3 Garg S. K., Garg R., Garg R., "Ecological and Environmental Studies", Khanna Publishers, First Edition, (2006).
4 Santra S. C., "Environmental Science", New Central Book Agency (P) Ltd., Second Edition, (2006).
5 Uberoi N. K., "Environmental Management", Excel Books, Second Edition, (2006).

Course Code	Course Title	L	T	P
CHX-457	Industrial Rheology	3	0	0

Introduction

Introduction to non Newtonian and non Newtonian fluid behaviour, time independent fluid behaviour, time dependent fluid behaviour (thixotropy and rheopexy), visco elastic fluids, dimensional considerations.

Rheometry for Non Newtonian Fluids

Capillary viscometers, rotational viscometers, normal stress measurements, Introduction and working of Capillary viscometers, rotational viscometers, stress rheometers.

Flow in pipes and in conduits of non-circular cross section

Fluid flow in laminar flow in circular tubes, power law fluids, bingham plastic, yield pseudo plastic fluids, generalized Reynolds no for time independent fluids, laminar flow in two infinite parallel plates, laminar flow in concentric annulus.

Heat Transfer Characteristics of non-Newtonian fluids in pipes

Laminar flow in circular tubes, full developed heat transfer to power law fluids in laminar flow.

Momentum heat and Mass transfer in boundary layers and liquid mixing

Integral momentum equation, laminar flow of power law liquids over a plate, Liquid mixing, scale up of stirred vessels, power consumptions in stirred vessels.

Recommended Books

1 Chabra, Richardson, "Non Newtonian fluids in Process Industries", Butterworth, Melbourne, (1999).

2 Bird, Stewart W. E. and Lightfort, "Transport Phenomena", John Wiley and Sons, (2002).

3 Welty J. R., Wilson R. E., Wicks C E, "Fundamentals of Momentum, Heat and Mass Transfer", 4th Edition, John Wiley and Sons, (2001).

4 Tanners R. I., "Rheology: An Historical perspective", Elsevier, Amsterdam, (1998).

5 Skelland, A. H. P., "Non Newtonian Flow and Heat Transfer", Wiley, New York, (1967).

Course Code	Course Title	L	T	P
CHX-459	Membrane Separation Processes	3	0	0

Introduction

Definition of membrane and membrane process, Commercial membrane separation processes, new membrane separation process under development

Reverse Osmosis and Nano filtration

Introduction and definition, theory and design, different membrane modules, selected applications and economics.

Ultra filtration

Introduction and definition, theory and design, membrane module and process configuration, applications and economics.

Micro filtration

Introduction and definition, theory of cross flow filtration, dead end micro filtration, applications and economics.

Emulsion liquid membranes

Introduction and definition, theory and design, selected applications and economics

Dialysis, Electodialysis, Pervaporation, Gas permeation
Brief introduction and applications.

Recommended Books

1 Wilson, Sirkar, "Membrane Handbook", McGraw Hill, London, (2001).

2 Nune, Peinemann, "Membrane Technology in Chemical Industries", Wiley, New York, (2000).

3 Cheryan M., "Ultra filtration Handbook", Technomic, New York, (1985).

4 Noble, Stern, "Membrane Separation and Technology, Principles and Applications", Elsevier, (1995).

5 Baker R. W., "Membrane Technology and Applications, Wiley, New York, (2000).

Course Code	Course Title	L	T	P
CHX-461	Optimization Techniques	3	0	0

Introduction
Introduction to optimization and its scope in chemical process design, Developing Models for Optimization, Formulation of the Objective Function.

Optimization Theory and Methods
Basic Concept of Optimization of Unconstrained Functions: One-Dimensional Search, Unconstrained Multivariable Optimization

Linear & Nonlinear Programming and Applications
Linear Programming (LP) and Applications, Nonlinear Programming with Constraints, Global Optimization for Problems with Continuous and Discrete Variables. Constrained multivariable optimization.

Mixed-Integer Programming & Examples
Mixed-Integer Programming, Optimization in Large-Scale Plant Design and Operations, Integrated Planning, Scheduling, and Control in the Process Industries, Process integration examples.

Application of Optimization
Heat Transfer and Energy Conservation, Separation Processes, Fluid Flow Systems, Chemical Reactor Design and Operation.

Recommended Books

1 Edgar T. F., Himmelblau, D. M., "Optimization of Chemical Process", McGraw Hill, (1989).

2 Urbanier K., McDermott C., "Optimal Design of Process Equipment" John, Wiley, (1986).

3 Reklaitis G. V., Ravindran A., Regsdell K. M., "Engineering Optimisation", John Wiley, New York, (1980).

4 Biles W. E., Swain, J. J., "Optimization and Industrial Experimentation", Inter Science, New York, (1980).

5 Seinfield J. H., Lapidus L., "Process Modelling, Estimation and Identification", Prentice Hall, Englewood Cliffs, New Jersey, (1974).

Course Code	Course Title	L	T	P
CHX-463	Petroleum Recovery Technology	3	0	0

Petroleum as a Resource Material

Indian Sedimentary basins, Types of rocks-Igneous rocks, Metamorphic rock, sedimentary rock, Kerogen and classification, Origin, Migrations and Accumulation of Hydrocarbons source, Migration of oil-mechanism pattern and barriers, Reservoir rocks and cap rocks, Entrapment of oil-types and mechanism etc.

Physical Properties of Reservoir Rock

Core analysis, conventional core analysis, conventional core analysis, Porosity, effective porosity, primary porosity, secondary porosity, porosity measurement, permeability, Effective permeability, fluid saturation, electrical resistivity, Darcy's law, Single and Multiphase flow etc.

Special Core Analysis

Wettability, capillary pressure characteristics, relative permeability, oil window etc. Flow of fluids through porous media: Darcy's law, single and multiphase flow. Reservoir flow through porous media, reservoir drive mechanism etc. Petroleum Exploration: Gravitational, Magnetic, Seismic, Electrical, Radioactive, Well logging methods etc.

Drilling

Introduction to on-shore and offshore drilling operations, onshore drilling techniques, cable tool drilling, rotary drilling, vertical drilling, Directional drilling, Horizontal drilling, Offshore drilling rigs, drilling accessories components, drilling fluid circulation system, functions of drilling fluids, Mud parameters.

Production

Production problems and work over operations, Well stimulation method, Hydraulic fracturing, matrix treatment, acidizing etc. Open Hole Logging: Electrical Surveys, Radioactive Surveys, Introduction to Well Logging: Mud logs, Pressure logs, Core logs, Wireline logs etc.

Improved Oil Recovery Techniques

Need of additional energy for pressure maintains of a reservoirs, techniques for various artificial lift methods sucker rod pumping, Immiscible, miscible, chemical and thermal, Chemical Recovery processes: Polymer flooding, micellar flooding, surfactant flooding, alkaline flooding. Thermal recovery processes: Steam drive, cyclic steam injection, in situ combustion etc.

Petroleum Reserve Estimation

Reserve categories, proven and unproven reserve, type of reserve, prognostic reserves, commercial reserves, balance reserve, zabalance reserve. Reserve estimation: volumetric method, material balance method, decline curve analysis, numerical simulation techniques, Monte Carlo approach etc.

Development of Oil and Gas Fields

Reservoir Drive Mechanism and recovery factor, concept of well spacing, Development of the Field, Technological Scheme for Development etc.

Recommended Books

1 Berger B. D., Anderson K. E., "Modern Petroleum" Penn well books.

2 Bradley H. B., "Petroleum Engineering Handbook", SPE.

3 Cole F. W., Reservoir Engineering manual.

4 Carl G., "Petroleum Engineering Drilling and Well Completions", Prentice Hall.

5 Mc Cray, Cole, "Oil Well Drilling Technology", Oklahoma Press.

Course Code	Course Title	L	T	P
CHX-465	Petroleum Refining Technology	3	0	0

Introduction to Petroleum Industry
World petroleum resources, petroleum industries in India. Scope and Purpose of Refining, Global and Indian refining scenario, Petroleum refining industry in India practice and prospects.

Refinery Distillation Processes
Desalting and Stabilization of crude, Process description of typical simple distillation, Fractional distillation, crude oil distillation, vacuum distillation etc, ASTM, TBP and EFV Distillation

Fuel Refining, Lube Refining and Wax Refining
Cracking, coking, reforming, alkylation, isomerisation, polymerization, sweetening, visbreaking. Solvent extraction, de-waxing, propane de-asphalting. De-oiling of crude wax, crystallization, catalytic, sweating microcrystalline and petroleum wax applications

Hydro processing
Hydro cracking, hydro treating, hydro finishing

Two Phase oil and gas separation equipment
Types, their description, vessel sizing. Theory of separation and separator design.

Three phase Oil, gas and water separators
Types of separators, their description. Various control and vessel internals, theory and sizing of three phase separator. LACT units

Safety and pollution considerations in refineries
Treatment methods, Sweetening, hydrodesulphurization, smoke point improvement.

Recommended Books

1 Nelson W. L., "Petroleum Refinery Engineering", McGraw Hill Book Co., (1985)

2 Watkins R. N., "Petroleum Refinery Distillation", Gulf Publishing Co.

3 Gary J. H., Handework G. E., "Petroleum Refining Technology and Economics", Marcel Dekker, Inc., (2001).

4 Jones D. S. J., "Elements of Petroleum processing", John Wiley & Sons, (1995).

5 Waquier J. P., "Petroleum Refining" Vol. I & II, Technip, (1995).

Course Code	Course Title	L	T	P
CHX-467	Polymer Science and Engineering	3	0	0

Basic Concepts
Concepts and classification of polymers, Functionality , Glass transition temperature, Addition, condensation, step-growth and chain-growth polymerization, Molecular weight estimation: Number and weight average, Sedimentation and viscosity average molecular weights, Molecular weight and degree of polymerization, Polydispersity, Significance of molecular weight.

Polymerization Processes
Bulk, solution, emulsion and suspension polymerization, Comparison of polymerization processes.

Polymerization Kinetics

Chemistry of step reaction polymerization, Mechanism and kinetics of poly condensation reactions, Relationship between average functionality, extent of reaction and degree of polymerisation. Mechanism and kinetics of free-radical chain polymerization, kinetic chain length, chain transfer reactions, Inhibition and retardation

Synthetic Fibres

Types of Fibres, Spinning Techniques, Manufacturing Technology and Applications of different types of fibres: cellulosic fibres, polyamides, acrylics, vinyls and vinylidines, fluorocarbons.

Plastics

Manufacturing Technology and applications of different types of plastics: Polyester, polyethylene, Phenolics, Rubbers, structure, properties and preparation natural rubber synthetic rubbers: SBR, rubber compounding and reclaiming.

Testing and Evaluation of plastics and rubbers

Physical testing, Electrical Properties, Softening Temperature tests, Melt flow Index.

Recommended Books

1 Gowariker V. R., Viswanathan N. V., Sreedhar J., "Polymer Science", New Age International Publishers, (1996).

2 Billmeyer F. W., "Text Book of Polymer Science", Wiley Tappers, (1994).

3 Ghosh P., "Polymer Science and Technology of Plastics and Rubber", Tata McGraw Hill, (2001).

4 Gupta R. K., Kumar A., "Fundamentals of Polymer Engineering", 2nd Edition, Marcel Dekkar, (2003).

5 Fried J. R. "Polymer Science and Technology", PHI Learning, (2008).

Course Code	Course Title	L	T	P
CHX-452	Computational Fluid Dynamics	3	0	0

Conservation laws
Governing equations of fluid flow and heat transfer–mass conservation, momentum and energy equation, differential and integral forms, conservation and non-conservation form.

Turbulence
Characteristics of turbulent flows, Time averaged Navier Stokes equations, Turbulence models–one and two equation, Reynolds stress, LES and DNS.

Finite volume method
Diffusion problems – explicit and implicit time integration; Convection-diffusion problems–properties of discretisation schemes, central, upwind, hybrid, QUICK schemes; Solution of discretised equations.

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

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

Recommended Books

1 Anderson J. D., "Computational Fluid Dynamics: The Basics with Applications", McGraw Hill, (1995).

2 Fletcher C. A. J., "Computational Techniques for Fluid Dynamics", Springer Verlag, (1997).

3 Versteeg H.K., Malalasekera W., "An Introduction to Computational Fluid Dynamics: The Finite Volume Method", Pearson Education Ltd., (2007).

Course Code	Course Title	L	T	P
CHX-454	Energy Management and Audit	3	0	0

Energy Scenario
Commercial and Non-Commercial Energy, Primary Energy Resources, Commercial Energy Production, Energy Needs of Growing Economy, Long Term Energy Scenario, Energy Pricing, Energy Sector Reforms, Energy and Environment: Air Pollution, Climate Change, Energy Security, Energy Conservation and its Importance, Energy Strategy for the Future, Energy Conservation Act-2001 and its Features. Kyoto Protocol. Global warming.

Energy Management & Audit
Definition, Types of energy audit, Energy management (audit) approach-understanding energy costs, Bench marking, Energy performance, matching energy use to requirement, Maximizing system efficiencies, Optimizing the input energy requirements, Fuel and energy substitution, Energy audit instruments.

Energy Action Planning
Key elements, Force field analysis, Energy policy purpose, perspective, Contents, Formulation, Ratification, Organizing - location of energy management, Top management support, Managerial function, Roles and responsibilities of energy manager, Accountability.

Motivating-motivation of employees
Information system designing barriers, Strategies; Marketing and communicating-training and planning.

Financial Management
Investment-need, Appraisal and criteria, Financial analysis techniques- Simple pay back period, Return on investment, Net present value, Internal rate of return, Cash flows, Risk and sensitivity analysis; Financing options, Energy performance contracts and role of ESCOs.

Project Management
Definition and scope of project, Technical design, Financing, Contracting, Implementation and performance monitoring. Implementation plan for top management, Planning Budget, Procurement Procedures, Construction, Measurement & Verification.

Energy Monitoring and Targeting
Defining monitoring & targeting, Elements of monitoring & targeting, Data and information-analysis, Techniques - energy consumption, Production, Cumulative sum of differences (CUSUM).

Recommended Books

1 Capehart, Barney L., Turner W. C., Kennedy W. J., "Guide to Energy Management", Third Edition, Fairmont Press, Atlanta, GA, (2000).

2 Thumann A., Mehta D. P., "Handbook of Energy Engineering", 4th Edition Lilburn, GA: Fairmont Press, (1997).

3 Loftness, Robert L. "Energy Handbook." 2nd Edition, New York: Van Nostrand Reinhold Co., (1984).

4 Turner W., "Energy Management Handbook", John Wiley &. Sons, New York, (1982).

5 Lapedes, D. N., "Encyclopaedia of Energy", McGraw-Hill, New York, (1976).

Course Code	Course Title	L	T	P
CHX-456	Industrial Environmental Management	3	0	0

Introduction
Introduction, Processes and Waste Characteristics, Pollution Control in Process and Waste Management according to the environment standards specific to the following types of Industries:

Chemical Process and Allied Industries
Pesticides Industry, Paint Industry, Pharmaceutical Industry, Fertilizer Industry, Sugar and Distillery Industry, Acids and Explosives Industry, Petroleum Refinery and Petrochemical Industry, Dyes and Dye-intermediate Industry, Pulp and Paper Industry, Leather Industry.

Food Processing and Allied Industries
Dairy Industry, Poultry Industry, Edible Oil Industry.

Textile and Allied Industries
Textile Industry, Man-made Fibre and Rayon Industry, Jute Processing Industry.

Metallurgical and Mining Industries
Iron and Steel Industry, Aluminium Industry, Copper Industry, Foundry Industry, Coal Mining Industry, Lead and Zinc Mining Industry.

Cement and Allied Industries
Cement Industry, Ceramic Industry, Lime and Brick Kiln.

Mechanical, Electrical, Electronics and Allied Industries
Metal Fabricating Industry, Electroplating Industry, Printing Industry, Electrical and Electronics Industry, Aerospace Industry.

Recommended Books

1 Dryden C. E., "Outlines of Chemical Technology", East-West Press Pvt. Ltd., Second Edition, (1973).

2 Austin G. T., "Shreve's Chemical Process Industries", McGraw Hill Book Company, Fifth Edition, (1986).

3 Bhatia S. C., "Handbook of Industrial Pollution and Control", CBS Publishers and Distributors, Volume I and II, First Edition, (2002).

4 Sell N. J., "Industrial Pollution Control-Issues and Techniques", Van Nostrand Reinhold Publication, Second Edition.

5 Hocking M. B., "Handbook of Chemical Technology and Pollution Control", Academic Press, Third Edition, (2005).

Course Code	Course Title	L	T	P
CHX-458	**Introduction to Multiphase Flow**	**3**	**0**	**0**

Flow past immersed bodies

Drag and drag coefficients, flow through beds of solids, motion of particles through fluids, fluidization, types of fluidization and applications.

Two-phase flow

Two–phase flow through pipes: Elementary aspects, Two phase Flow pattern in vertical and Horizontal pipes. Two phase pressure drop calculation in Homogeneous and separated flow model for flow inside tube. Lockhart-Martinelli parameters and their application in analysis of two-phase flows.

Interaction of fluids

Mixing of a single fluid; degree of segregation, early and late mixing of fluids, models for partial segregation, mixing of two miscible fluids. Gas-liquid flow phenomenon, Types of regimes formation – trickle, pulse, bubble, dispersed bubble, spray regime etc.

Types of Multiphase-Reactors

Various types of multiphase reactors. e.g. Packed bed, packed-bubble column, trickle bed reactor, three phase fluidized bed reactor, Bubbling Fluidized Bed (BFB), Circulating Fluidized Bed (CFB), slurry bubble column, and stirred tank reactor. Characteristics of above mentioned reactors such as; fluid flow phenomena and flow regimes, flow charts/correlations, pressure drop, liquid hold up etc. Reactors involving Newtonian and non-Newtonian fluids.

RTD in Multiphase Flow systems

Non Ideal Flow: Residence time distribution of fluid in vessel, E, F & C Curve, Mean and variance, the Dirac delta function, residence time, linear and non-linear processes, models for non ideal flow, dispersion model, N tanks in series model, model for small deviations from plug flow and long tails, conversion in a reactor using RTD data, diagnosing ills of operating multiphase reactors, models for multiphase reactors. Two parameter model; PD model; three parameter models; PE Model.

Recommended Books

1 Levenspiel O., "Chemical Reaction Engineering", 3rd Edition, John Wiley & Sons, Singapore, (1999).

2 Fogler H. S., "Elements of Chemical Reaction Engineering", 3rd Edition, Prentice Hall Inc., (1999).

3 Shah Y.T., "Gas-Liquid-Solid Reactor Design", McGraw Hill Int. New York, (1979).

4 Westerterp K. R., van Swaaij W. P. M., Beenackers A. A. C. M., "Chemical Reactor Design and Operation", John Wiley & Sons, (1993).

5 Doraiswamy L. K., Sharma M. M., "Heterogeneous Reactions: Volume 2 Fluid-Fluid-Solid Reaction", John Wiley & Sons, Singapore, (1984).

Course Code	Course Title	L	T	P
CHX-460	Instrumental Methods of Analysis	3	0	0

Introduction to Chemical Analysis

Qualitative and Quantitative analysis, fundamental theory of solution reactions i.e. chemical equilibrium, buffer solutions, hydrolysis, ionic product, solubility product, electrolytic dissociation, electrode potential, common ion effect, complex ion

Data Analysis

Error, accuracy, precision, significant figures, correlation, regression, analysis of variance, optimization methods, factor analysis

Titrimetric Analysis

Classification of reactions, standard solutions, Principles of Potentiometric titrations, Spectrophotometric titrations, Neutralization titrations, Complexation titrations, Redox titrations, Precipitation titrations

Spectroscopic Analysis

Introduction, theory and principles of Atomic Absorption Spectroscopy, Atomic Emission Spectroscopy, Mass Spectroscopy, Nuclear Magnetic Response Spectroscopy, Infrared Spectroscopy, Raman Spectroscopy

Chromatographic Analysis

Introduction, theory, principles and methodology of Thin Layer Chromatography, Liquid Chromatography and Gas Chromatography

Thermal Analysis

Introduction, theory, principles and methodology of Thermo Gravimetric (TG), Differential Thermo Gravimetric (DTG), Derivative Thermal Analysis (DTA) and Differential Scanning Calorimetry (DSC)

Electrochemical Analysis

Introduction, theory, principles and methodology of Electrogravimetric analysis, Coulometry, Potentionmetry, Voltammetry, Polarography

Recommended Books

1 Mendham J., Denney R. C., Barnes J. D., Thomas M. J. K., "Vogel's Text Book of Quantitative Chemical Analysis", Pearson Education, Sixth Edition, (2006).

2 Willard, Merritt, Dean, Settle, "Instrumental Methods of Analysis", CBS Publisher and Distributors. (1986).

3 Haines J., Blackie, "Thermal methods of Analysis, Principles, Application and Problems", Academic and Professional, (1994).

4 Braithwaite A., Smith F. J., "Chromatographic Methods", Fifth Edition, Blackie Academic and Professional, London, (1996).

5 Skoog, Holder, Nieman, "Principles of Instrumental Analysis", Fifth Edition, Thomson Books, (1998).

Course Code	Course Title	L	T	P
CHX-462	Natural Gas Engineering	3	0	0

Gas from condensate and oilfields

Scope of Natural gas industry. Basic thermodynamic and system energy concepts in Natural Gas Engineering. Review of physical and chemical properties of natural gas and associate hydrocarbons. Phase behaviour studies of two phase hydrocarbon systems, equations of states, multiple flashes. Water-hydrocarbon system. Vapour liquid equilibria.

Flow of fluids
Compression calculations. Heat Transfer and Mass Transfer principles and applications in Natural Gas Engineering. Gas flow measurement. Process control and instrumentation in natural gas processing plants.

Natural Gas Processing
Field separation and oil absorption process. Refrigeration and low temperature processing. Liquification process. Dehydration of Natural Gas sweetening of Natural gas and sulphur recovery, Processing for LPG, LNG, CNG system.

Transmission of Natural Gas
Specifications. Utilization of Natural Gas. Underground storage and conservation of Natural Gas

Unconventional Gas
Coal Bed Methane, Natural Gas Hydrate. Conversion of gas to liquid. Economic consideration for development of gas fields.

Recommended Books

1 Kumar S., "Gas Production Engineering", Gulf Publishing Co., (1987).

2 Beggs H. D., "Gas Production Operations", OGCI Publication, (1984).

3 Ikoku C. K., "Natural Gas Engineering", John Wiley, (1984).

4 Alexandre R., "Natural Gas: Production, Processing and Transport", Hyperion Books, (1995).

5 Katz D. L., "Hand Book of Natural Gas Engineering", McGraw Hill.

Course Code	Course Title	L	T	P
CHX-464	**New and Renewable Energy Resources**	**3**	**0**	**0**

Introduction
Global and Indian scenario, Sources, Energy conservation, Types of NCES with applications, Role and development of new renewable energy sources

Solar Energy
Introduction, Solar radiation data, Instruments for measuring solar radiations, Flat plat and concentrating collectors, Classification of concentrating collectors, Advanced collectors, Different methods of solar energy storage, Solar ponds, Solar applications: Solar heating/cooling technique, solar distillation and drying, photovoltaic energy conversion. Solar Calculations: Angles associated with solar rays and the collector surface, Local apparent time, Soar day length

Geothermal Energy
Resources, Types of wells, Methods of harnessing the energy

Wind Energy
Sources and potentials, Horizontal and vertical axis wind mills, Wind regime analysis and evaluation of wind mills

Biomass and Biofuels
Recycling of agricultural waste, Anaerobic/aerobic digestion and types of biogas digesters, Gas yield and combustion characteristics of bio gas, Design of biogas system for heating, Lighting and running IC engines. Introduction to Biofuels such as biodiesel, ethanol, biobutanol etc. and their production and present status.

Ocean and Tidal Energy
OTEC, Settling of OTEC plants, Thermodynamic cycles, Tidal Energy: Potential and conversion techniques, mini hydel power plants and their economics.

Recommended Books

1 Rai G. D., "Non-conventional Energy Sources", Standard Publishers Distributors, (2007).

2 Sukhatme K., Sukhatme S. P., Solar Energy: Principles of Thermal Collection and Storage, 2nd Edition, Tata McGraw Hill, (1996).

3 Desai A. V., "Non-convetional Energy", Wiley Eastern, (1990).

4 Mittal K. M., "Non-conventional Energy System", Wheeler Publishing Co. Ltd, (1997).

5 Rao S., Parulekar B. B., "Energy Technology", Khanna Publishers, (1995).

Course Code	Course Title	L	T	P
CHX-466	Petrochemical Technology	3	0	0

Petrochemical - an overview
Growth of global and Indian petrochemicals industries. Definition of Petrochemicals, History of Petrochemicals Industry, Development of Petrochemicals Industry in India, Economics of Petrochemicals Industry, general cost considerations, indigenous technology V/S foreign know-how. Sources of petrochemicals-Natural gas and petroleum, classification of petrochemicals.

Chemicals from methanol and synthesis gas
Oxo-products, methanol, formaldehyde, carbon-di-sulphide, Hydrogen cyanide.

Chemicals from ethane, ethylene and acetylene
Synthetic ethanol, aldehyde, acetaldehyde, acetic acid, vinyl acetate, butraldehyde and ethyl hexanol and DOP; ethylene oxide, ethylene glycol, acrylonitrile, ethanol, amines, ethyl chloride, ethylene di chloride

Chemicals from propane and propylene
Iso-propanol, acetone, glycerol, propylene oxide, propylene glycols, isoprene, cumene.

Chemicals from butanes, butane pentanes and pentanes
Butadiene, butone, epoxides,butanol amines, butyl acetate, methyl-ethyl ketone

Chemicals from aromatics
monochloro, dichloro benzene, BHC nitro benzene, dodecyl benzene, benzoic acid, nitrotoluene, pthalic anhydride, isopthalic acid, terethalic acid, dimethyl terepthalate, maelic anhydride, adipic acid, hexamethylene diamine

Future of Petrochemicals
Integrated petro chemical complex, energy crisis in petro chemical industries, natural gas as petro chemical feed stock, import of heavy feed stocks on petro chemicals, ecology and energy crisis. Coal as an alternative to oil, energy crisis and industrial fuel, synthetic fuels, trends in petro chemical industries.

Recommended Books

1 Rao B. K. B., "A textbook on Petrochemicals" 2nd Edition, Khanna publisher, (1996).

2 Ram Prasad , "Petroleum Refining Technology", Khanna publisher

3 Sukumar M., "Introduction to Petrochemicals", Oxford and IBH publishing Co., (1992),

4 Chauvels A., Lefebvre G., "Petrochemical Process", Vol. 4.

Course Code	Course Title	L	T	P
CHX-468	Process Plant Utilities	3	0	0

Steam

Boilers-classification, various types, construction, boiler mountings & accessories, properties of steam-tables, Mollier Diagram.

Power Generation

Internal Combustion Engines - classification, two- stroke, four stroke petrol & diesel engine, valve timing diagram, carburetor, Combustion Phenomena

Refrigeration

Air refrigeration cycles, vapour compression cycle, P-H diagram, liquification processes.

Compressed Air and Vacuum

Use of compressed air, classification of compressors. Reciprocating compressors-mechanical details, single stage and two stage reciprocating compressor, inter cooler, minimum work input in multistage. Centrifugal compressor-velocity diagram for centrifugal compressors, dimensional parameters, slip factor, impeller blade shapes, losses in axial flow compressors.

Fuel

Natural gas, liquid petroleum fuels, coal & Coke.

Waste Disposal:

Plant sewer system and waste disposal.

Recommended Books

1 Yadav R., "Thermodynamics & Heat Engines", Central Publishing House.

2 Vasandani, "Treatise on Heat Engines".

3 Lyle O., "The efficient use of steam",Her Majesty's Stationary Ofiice, London (1968).

4 Barrow H. M., "Preliminary Chemical Engineering Plant Design", New York.

5 Dodge B. F., "Chemical Engineering Thermodynamics", McGraw Hill.

Course Code	Course Title	L	T	P
CHX-471	Environmental Engineering	3	0	0

Air Pollution Control Engineering

Introduction, Definition, Sources, Characteristics and Perspective of Air Pollutants, Effects of Air Pollution on Biodiversity, Economic Effects of Air Pollution, Air Quality and Emission Standards, Engineering Systems of Control of Air Pollution by Equipment and by Process Changes.

Water Pollution Control Engineering

Introduction, Definition, Sources, Characteristics and Perspective of Water and Wastewater Pollutants, Effects of Water Pollution on Biodiversity, Economic Effects of Water Pollution, Water Quality and Emission Standards, Physical, Chemical and Biological Parameters, Engineering Systems of Control of Water and Wastewater Pollution by Primary, Secondary and Advance Treatment.

Solid Waste Management

Introduction, Definition, Sources, Characteristics and Perspective of Solid Waste, Generation, Separation, Handling, Storage and Transportation of Solid Waste, Chemical and Biological Treatment of Solid Waste.

Biomedical and Hazardous Waste Management

Introduction, Definition, Sources, Characteristics and Perspective of Biomedical and Hazardous Waste, Handling, Storage, Transportation of Biomedical and Hazardous Waste, Physical, Chemical and Biological Treatment of Biomedical and Hazardous Wastes.

Recommended Books

1 Rao M. N., Rao H. V. N., "Air Pollution", Tata McGraw Hill Publishing Company Ltd., (2005).

2 Peavy H. S., Rowe D. R., Tchobanoglous G., "Environmental Engineering", McGraw Hill Book Company, International Edition, (1985).

3 Metcalf and Eddy, Inc., "Wastewater Engineering-Treatment and Reuse", Tata McGraw Hill Publishing Company Ltd., Fourth Edition, (2004).

4 Rittmann B. E., McCarty P. L., "Environmental Biotechnology: Principles and Application", McGraw Hill International Editions, First Edition, (2001).

5 Kiely G., "Environmental Engineering", Tata McGraw Hill Publishing Company Ltd, Special Indian Edition, (2007).

Course Code	Course Title	L	T	P
CHX-472	Hydrocarbon Engineering	3	0	0

Scope and Purpose of Refining

Global and Indian refining scenario, Petroleum refining industry in India practice and prospects, Separation and Conversion processes etc.

Refinery Distillation Processes

Desalting, Process description of typical crude distillation, Fractional distillation, Vacuum distillation, Flooding, Weeping, Entrainment, Setting of cut point, Crude assay analysis, ASTM, TBP EFV Distillation etc.

Fuel Refining and Lube Refining

Cracking, Coking, Reforming, Alkylation, Isomerisation, Polymerization, and Sweetening etc. Solvent extraction, De-waxing, Propane deasphalting etc.

Hydro processing

Hydro cracking, Hydro treating, Hydro desulphurization

Oil and Gas separators
Principal of separation, Types of separators, their description. Various control and vessel internals, Oil and gas gravitational separator, Vertical two and three phase separator, Horizontal three phase separator etc.

Quality Monitoring of Petroleum Products
API gravity, Flash point, Fire point, Smoke point, Aniline point, Carbon residue, Kinetic viscosity, Pour point, Freezing point, octane number, Cetane number, Viscosity index, Diesel index Calorific value, Burning test 24 hours, Characterization factor, Cloud Point, Vapour lock index, Carbon hydrogen ratio, Calculated ignition index, Calculated carbon aromaticity index, U.O.P Characterization factor, Conrad son carbon residue, Water and sediment content etc.

Storage of Petroleum Products
Classification of inflammable liquids, Classification of storage tank, Floating roof tank, Fixed roof tank, Semi buried tank, Import/export loss, Breathing losses, Hazards and non-hazards area, and underground storage tank etc.

Transportation
Transportation of oil and natural gas by rail, road and pipeline, Various type of pipelines, Pipe line automation, Lease Automatic Custody Transfer units, SCADA, Batch transport of petroleum products, Multiproduct pipelines, Product handling, Pumping cycle, Interface , Problems in waxy crude, Role of flow behaviour etc.

Marketing of Petroleum and Petroleum products
Role of International oil companies and OPEC pricing mechanism, Administered and market determined pricing mechanism in India.

Natural gas
Structural analysis of gas industry, Types of natural gas, Units of natural gas, Impurities of natural gas, Natural gas quality, LNG Scenario in India etc.

Recommended Books

1 Nelson W. L., "Petroleum Refinery Engineering", Mc Graw Hill Book Co. ,(1985).

2 Watkins R. N., "Petroleum Refinery Distillation", Gulf Publishing Co.

3 Gary J. H., Handwork G. E., "Petroleum Refining Technology and Economics", Marcel Dekker, Inc., (2001).

4 Jones D. S. J., "Elements of Petroleum processing", John Wiley & Sons, (1995).

5 Waquier J. P., "Petroleum Refining" Vol. I & II , Technip, (1995)

Course Code	Course Title	L	T	P
CHX-473	**Industrial Safety & Hazards Management**	**3**	**0**	**0**

Introduction
Concept of Loss prevention, acceptable risks, accident and loss statistics, nature of accident process, inherent safety.

Toxicology
Dose vs. response, toxicants entry route, models for dose and response curves, TLV and PEL

Industrial Hygiene
Identification, Material safety data sheets, Industrial hygiene evaluation, and control

Basics of Fires and Explosion

Fire triangle, definitions, flammability characteristics of liquid and vapors, LOC and inerting, types of explosions, Designs for fire prevention:

Hazard identification
Hazard survey, checklist, HAZOP, safety reviews, what if analysis

Risk Assessment
Probability theory, event tree, fault tree, QRA and LOPA, Dow's fire and explosion index, Mond index, Dow's Chemical release model

Accident Investigations and Case Histories

Bhopal gas tragedy, flixborough disaster, Pasadena accident, IOCL Jaipur fire

Recommended Books

1 Crowl D. A., Louvar J. F., "Chemical Process Safety Fundamentals with applications", (2002), 2nd Edition, Prentice Hall, NJ.

2 Coulson J. M., Richardson J. F., "Chemical Engineering", 2nd Edition, Vol 6, Pergamon Press, (1999).

3 Dow's Chemical Exposure Index Guide, Dow Chemical Company, New York, (1993).

4 Lees F P, Loss prevention in process Industries, 2nd Edition, Butterworth, London, (1996).

5 Wells G L, Safety in process Plant Design, George Godwin Ltd., New York, (1980).

Course Code	Course Title	L	T	P
CHX-474	New and Renewable Energy Resources	3	0	0

Introduction
Global and Indian scenario, Sources, Energy conservation, Types of NCES with applications, Role and development of new renewable energy sources

Solar Energy
Introduction, Solar radiation data, Instruments for measuring solar radiations, Flat plat and concentrating collectors, Classification of concentrating collectors, Advanced collectors, Different methods of solar energy storage, Solar ponds, Solar applications: Solar heating/cooling technique, solar distillation and drying, photovoltaic energy conversion. Solar Calculations: Angles associated with solar rays and the collector surface, Local apparent time, Soar day length

Geothermal Energy
Resources, Types of wells, Methods of harnessing the energy

Wind Energy
Sources and potentials, Horizontal and vertical axis wind mills, Wind regime analysis and evaluation of wind mills

Biomass and Biofuels
Recycling of agricultural waste, Anaerobic/aerobic digestion and types of biogas digesters, Gas yield and combustion characteristics of bio gas, Design of biogas system for heating, Lighting and running IC engines. Introduction to Biofuels such as biodiesel, ethanol, biobutanol etc. and their production and present status.

Ocean and Tidal Energy
OTEC, Settling of OTEC plants, Thermodynamic cycles, Tidal Energy: Potential and conversion techniques, mini hydel power plants and their economics.

Recommended Books

1 Rai G. D., "Non-conventional Energy Sources", Standard Publishers Distributors, (2007).

2 Sukhatme K., Sukhatme S. P., Solar Energy: Principles of Thermal Collection and Storage, 2nd Edition, Tata McGraw Hill, (1996).

3 Desai A. V., "Non-convetional Energy", Wiley Eastern, (1990).

4 Mittal K. M., "Non-conventional Energy System", Wheeler Publishing Co. Ltd, (1997).

5 Rao S., Parulekar B. B., "Energy Technology", Khanna Publishers, (1995).

Course Code	Course Title	L	T	P
CHX-475	Polymer Science and Engineering	3	0	0

Basic Concepts

Concepts and classification of polymers, Functionality , Glass transition temperature, Addition, condensation , step- growth and chain –growth polymerization, Molecular weight estimation: Number and weight average, Sedimentation and viscosity average molecular weights, Molecular weight and degree of polymerization, Polydispersity, Significance of molecular weight.

Polymerization Processes

Bulk, solution, emulsion and suspension polymerization, Comparison of polymerization processes.

Polymerization Kinetics

Chemistry of step reaction polymerization, Mechanism and kinetics of poly condensation reactions, Relationship between average functionality, extent of reaction and degree of polymerisation. Mechanism and kinetics of free-radical chain polymerization, kinetic chain length, chain transfer reactions, Inhibition and retardation

Synthetic Fibres

Types of Fibres, Spinning Techniques, Manufacturing Technology and Applications of different types of fibres: cellulosic fibres, polyamides, acrylics, vinyls and vinylidines, fluorocarbons.

Plastics

Manufacturing Technology and applications of different types of plastics: Polyester, polyethylene, Phenolics, Rubbers, structure, properties and preparation natural rubber synthetic rubbers: SBR, rubber compounding and reclaiming.

Testing and Evaluation of plastics and rubbers

Physical testing, Electrical Properties, Softening Temperature tests, Melt flow Index.

Recommended Books

1 Gowariker V. R., Viswanathan N. V., Sreedhar J., "Polymer Science", New Age International Publishers, (1996).

2 Billmeyer F. W., "Text Book of Polymer Science", Wiley Tappers, (1994).

3 Ghosh P., "Polymer Science and Technology of Plastics and Rubber", Tata McGraw Hill, (2001).

4 Gupta R. K., Kumar A., "Fundamentals of Polymer Engineering", 2nd Edition, Marcel Dekkar, (2003).

5 Fried J. R. "Polymer Science and Technology", PHI Learning, (2008).

Course Code	Course Title	L	T	P
CHX-476	Oil and Natural Gas Economics	3	0	0

Role of Oil and Gas in the World Economy
Importance of Oil and Gas, Oil and Gas Reserves, Supply and Demand, Specific Features of Oil and gas Industries.

Oil and Gas Production and Development
Exploration for Oil and Gas, Economic Cost of Finding Oil and Gas, Contractual Arrangements for Exploration of Oil and Gas, Development of Oil and gas Fields, Economics of Oil and Gas Field Development, Technological Innovations in Exploration and Drilling etc.

Transportation and Processing of Oil and Natural Gas
Economics and Technologies for Transportation, Refinery Economics and Refining Technologies, Gas Processing Technologies and Economics, Optimization Techniques for Transportation and Processing etc.

Organization of Oil and gas Industries
Evolution of the Oil Industry, Domination by Multinationals OPEC Era, Recent Developments, Evolution of the Gas Industry, Gas Contracts, Deregulation and Restructuring in Oil and Gas Industries

Pricing of Oil and Gas
Economic Theory of Exhaustible Resources, Analysis of Oil Pricing by Multinational Companies, OPEC Pricing Policy, Net-Back Pricing and Parity Pricing, Pricing in a Competitive Market, Rent and Rent Sharing, Analysis of International Pricing of Oil and gas

Domestic Pricing Issues in Oil and Natural Gas
Objectives for Oil and Gas Pricing at the National level. Pricing Mechanisms and Policies, Tax and Subsidies etc.

Trade and markets for Oil and Natural Gas
International Oil and gas Markets, New Trading Mechanisms, Trading in a Deregulated Industry etc.

Issues Facing Oil and Gas Industries
Externalities, Financing Needs, Geo-Political Concerns

Recommended Books

1 Conaway C.F., "The Petroleum Industry: A Non- Technical Guide", Penn Well, (1999).

2 Berger B. D., "Modern Petroleum: A Basic Primer of the Industry", (1992).

3 Tussing A., Tippee B., "The Natural Gas Industry: Evolution, Structure and Economics", Penn Well, (1995).

4 Julius D., Mashaekhi, A., "The Economics of Natural Gas: Pricing, Planning and Policy", OIES, (1990).

5 Van Groenendaal W., "The Economics Appraisal of Natural Gas Projects", OIES, (1998).

Courses to be taught to the students of B. Tech. Bio Technology

The following courses are to be taught to the students of B. Tech. Bio Technology

Course Code	III Semester	L	T	P
CHX-381	Fluid and Particles Mechanics	3	0	0
	IV Semester			
CHX-382	Heat and Mass Transfer	3	1	0
	VI Semester			
CHX-302	Instrumentation and Process Control	3	1	0

Course Code	Course Title	L	T	P
CHX-381	**Fluid and Particle Mechanics**	**3**	**0**	**0**

Introduction to Fluid flow
Ideal and real fluids, Extensive and Intensive properties, viscosity, surface tension, capillarity, evaporability, vapour pressure, Newtonian and Non Newtonian fluids.

Fluid Statistics
Hydro statistics law, Pascal's law, Different types of Manometer, centrifugal decanter

Fluids Kinematics and Dynamics
Classification of fluid flow, streamline, streakline, pathlines, flow rate and continuity equation, Bernaulli's theorem and its application, kinetic energy and momentum correction factor in Bernaulli's equation, concept of friction law in fluid flow, various pumps.

Laminar Viscous flow and flow measurement devices
Reynolds numbers, Hagen Poiseuille Law, Venturi meter, Orifice meter.

Size Reduction
Particle size and shape, particle mass, size and shape distributions, measurement and analysis, concept of average diameter, size reduction, crushing, grinding and law of grindings.

Screening
Equipment, capacity and effectiveness of screen, effect of mesh size on capacity of screen.

Settling
Flow around a single particle, drag force and drag coefficient, settling velocity of particles in a fluid, hindered and free settling of particles, thickening gravity separation

Separation of solid from liquid
Classification of filters, various types of cake filters, principle of cake filtration, clarification filters, liquid clarification, centrifugal settling process.

Agitation & Mixing
Agitation of liquids, axial flow impellers, radial flow impellers, velocity and power consumption of agitated vessels, blending & mixing.

Fluidization
Packed beds, bed porosity, flow though a bed of particles, fluidization & fluidized bed, conditions for fluidization minimum velocity, types of fluidization

Recommended Books

1 Smith J. C., McCabe W. L., Harriot P. H., "Unit Operations of Chemical Engineering", McGraw Hill, 7th Edition, (2005).

2 Richardson, Coulson "Chemical Engineering Vol II", 5th Edition, Butterworth–Heinemann (2003).

3 Perry's, "Handbook of Chemical Engineering", 7th Edition, McGraw Hill (1997).

Course Code	Course Title	L	T	P
CHX-482	Heat and Mass Transfer	3	1	0

Conduction

Fourier's law, Steady state heat conduction through a composite solid, cylinders, spheres, Different insulating materials for process equipment.

Convection

Convection, Individual and overall heat transfer coefficient, Heat transfer between fluids separated by plane wall and by cylindrical wall (pipes), Critical/ optimum insulation thickness, Concepts of heat exchanger. Heat Transfer with phase change: Boiling phenomena, correlation for nucleate boiling, Critical heat flux, Condensation phenomena, Film condensation on a vertical surface.

Radiation

Blackbody radiation, Planck's law, Wein's displacement law, Stefan Boltzmann law, Kirchoff's law.

Mass Transfer

Mass Transfer Coefficient: Local and overall mass transfer coefficient, Local two phase mass transfer coefficients, Local overall Mass Transfer coefficients. Evaporation: Single and multiple effect evaporators, capacity and economy, boiling point elevation Gas Absorption: Choice of solvent, Number of ideal stages, Height of column, Equipment for gas absorption.

Drying & Distillation

Drying, Equilibrium in drying, Rate of batch drying, Time of drying, Drying equipments. Raoult's Law and Dalton's law in distillation, Partial vaporisation condensation, Relative volatility, Differential & flash distillation, Steam distillation, Total reflux , Minimum and optimum reflux ratios, Lewis Sorel and McCabe –Thiele methods.

Extraction & Adsorption

Liquid – Liquid Extraction, Ternary phase diagrams & choice of solvent, Single stage and multistage cross current, co-current and counter current extraction operation. Adsorption, Introduction and the nature of adsorbent, Adsorption equilibria, Langmuir isotherm, BET isotherm and Gibbs isotherm, Adsorption equipments.Crystallization, Formation and properties of crystals, Crystallisers.

Recommended Books

1 Smith J. C., McCabe W. L., Harriot P. H., "Unit Operations of Chemical Engineering", McGraw Hill, 7th Edition, (2005).

2 Richardson, Coulson "Chemical Engineering Vol II", 5th Edition, Butterworth –Heinemann, (2003).

3 Perry's, "Handbook of Chemical Engineering", 1997, 7th Edition, McGraw Hill.

4 Geankopolis C. J., "Transport Processes and Separation Process Principles", 4th Edition, PHI Eastern Economy Edition, (2004).

5 Treybal R. E., "Mass Transfer Operations", 3rd Edition, McGraw Hill, (1980).

Course Code	Course Title	L	T	P
CHX-302	Instrumentation and Process Control	3	1	0

General principles of measurement

Static and dynamic characteristics of instruments, Temperature Measurement: Thermocouples, resistance thermometers, thermistors, optical and radiation pyrometers. Pressure Measurement: Use of manometers, Bourdon gauge, bellows type gauge, measurement of vacuum and pressure transducers. Flow Measurement: Variable area meters. Pressure probes, positive displacement type meters. Liquid level Measurement: Direct and differential method, measurement in open and pressure vessels, measurement of liquid.

Process control

Laplace Transform: Transforms of simple function, Transforms of Derivative, Initial value theorem and Final value theorem, Transform of Integral

Response of First order systems and higher order systems

Mercury thermometer & its transfer function, Forcing functions, Liquid Level System, Liquid Level Process with constant flow out let, Linearization, Mixing tank & R.C. Circuit**,** Response of First order system in series: Non interacting System and Interacting Systems. Transfer function of second order system, under damped System, Impulse function, Sinusoidal function, Transportation lag

Controllers and final control element

Control Valve, Proportional controller, Integral & Derivative controller, Comparison of P, PI and PID controllers.

Transient response of control system

Components of control system, block diagram, Negative and Positive feedback, Servo problem and Regulation Problem, Development of Block diagram. Proportional control for set point change, Proportional control for load change, Proportional Integral control for load change, Proportional Integral Control for set point change

Stability of the system

Concept of stability, Stability Criteria, Routh test for stability. Introduction to frequency response: Bode diagram for first order, Bode diagram for proportional, Integral and derivative control, Second order system. Control System Design by frequency response: Bode stability criteria, Gain and phase Margin, Ziegler Nichols Controller settings.

Recommended Books

1 Coughanower D. R., "Process System Analysis and Control", 1991, 2nd Edition, McGraw Hill.

2 Seborg, E., Mellichamp, "Process Dynamics & Control", 2nd Edition, John Wiley, (2004).

3 Stephanopoulos, "Chemical Process Control-An Introduction To Theory & Practice", 1st Edition, Prentice Hall Inc.

4 Eckman D. P., "Industrial Instrumentation", Wiley Eastern Ltd., (1975).

5 Kerk F. W., Rimboi W., Tarapore R., "Instrumentation", Wiley and Sons, (1983).