SEMESTER WISE COURSE STRUCTURE

&

EVALUATION SCHEME

B. TECH. DEGREE PROGRAMME
IN CHEMICAL ENGINEERING

(Effective from the session 2019-20 for new entrants)

DEPARTMENT OF CHEMICAL ENGINEERING
HARCOURT BUTLER TECHNICAL UNIVERSITY
KANPUR

Chemical Engineering Department

OUR VISION

To emerge as a global leader in the areas of education and research in Chemical Engineering to handle the technological challenges in Chemical Engineering & Allied Fields and catering the requirements of stakeholders and society.

OUR MISSION

The missions of the Department of Chemical Engineering are:

M1: To provide state-of-art technical education to the undergraduate and post graduate students.

M2: To create a conducive and supportive environment for the overall growth of our students.

M3: To cultivate awareness of social responsibilities in students to serve the society.

M4: To groom students with leadership skills helpful in Startups, professional ethics and accountability along with technical knowledge to face the changing needs of industry and environment.

M5: To provide consultancy services to the Chemical and Allied industries of the region, state and the country.

For UG

Program Educational Outcomes (PEOs)

The educational objectives of B.Tech. Chemical Engineering are:

PEO1: Graduates from our department will be proficient in varied areas of Chemical Engineering that are industrially and academically significant such as Petroleum Refining, Petro Chemicals, Instrumentation & Process Control, Modeling & Simulation, Nanotechnology, Electrochemical technology, Process Engineering & Design along with recent advances.

PEO2: Graduates will exhibit entrepreneurship, leadership and high professional skills while maintaining ethical and moral values.

PEO3: Graduates will continuously strive and align their activities for betterment of the society.

PEO4: Graduates will discharge their duties with professional attitudes and ethics.

Program Specific Outcomes (PSOs)

The Program specific outcomes (PSOs) of B.Tech. Chemical Engineering are:

1. Design and development of eco-friendly, energy efficient and sustainable chemical engineering processes.

2. Apply the knowledge and analytical ability to solve problems related to chemical process industry.

3. Analyze and formulate economically viable solutions for environmental and waste management systems.

B.Tech. Chemical Engineering (Effective from 2019-20 Entrants)

Year I, Semester-I

Sl. No.	Course Type	Course Code	Subject	Credit	Sessional Marks				ESE	Total Marks
					MSE	TA	Lab.	Total		
1	BSC	BCY-151	Engineering Chemistry	4 [3-0-2]	15	20	15	50	50	100
2	BSC	BMA-151	Mathematics-I	4 [3-1-0]	30	20	-	50	50	100
3	ESC	EET-151	Electronics & Instrumentation Engineering	3 [3-0-0]	30	20	-	50	50	100
4	ESC	ECE-151	Engineering Graphics	3 [2-4-0]	30	20	-	50	50	100
5	ESC	ECS-151	Computers Concepts & Programming	4 [3-0-2]	15	20	15	50	50	100
6	ESC	EWS-151	Workshop Practice	2 [0-0-4]		20	30	50	50	100
7	MC (Non Credit)	ECE-153	Environment and Ecology	0 [2-0-0]	30	20	-	50	50	100
			Total Credits	**20**						600

Year I, Semester-II

Sl. No.	Course Type	Course Code	Subject	Credit	Sessional Marks				ESE	Total Marks
					MSE	TA	Lab.	Total		
1	BSC	BPH- 152	Physics	4 [3-0-2]	15	20	15	50	50	100
2	BSC	BMA-152	Mathematics-II	4 [3-1-0]	30	20	-	50	50	100
3	ESC	EEW- 152	Electrical Engineering	4 [3-0-2]	15	20	15	50	50	100
4	ESC	EME- 152	Engineering Mechanics	3 [3-0-0]	30	20	-	50	50	100
5	HSMC	HHS- 152	English Language and Composition	2 [2-0-0]	30	20	-	50	50	100
6	HSMC	HHS- 154	Professional Communication	3 [2-0-2]	15	20	15	50	50	100
			Total Credits	**20**						600

Year II, Semester-III

Sl. No.	Course Type	Subject Code	Course Title	Credits	Sessional Marks				ESM	Total marks
				(L-T-P)	MSE	TA	Lab.	Total		
1	BSC	BMA251	Mathematics III	4 [3-1-0]	30	20	-	50	50	100
2	ESC	TCH 251	Chemical Engineering Fluid Mechanics	5 [3-1-2]	15	20	15	50	50	100
3	PCC	TCH 253	Particle and Fluid Particle Processing	3 [3-0-2]	15	20	15	50	50	100
4	PCC	TCH 255	Process Heat Transfer	4 [2-1-2]	15	20	15	50	50	100
5	PCC	TCH 257	Chemical Process Calculations	3 [2-1-0]	30	20	-	50	50	100
6	HSMC	HHS 253	Organizational Behavior	3[3-0-0]	30	20	-	50	50	100
7	MC (Non Credit)	ECS 259	Cyber Security	0[2-0-0]	30	20	-	50	50	100
Total Credits				**22**						

Year II, Semester-IV

Sl. No.	Course Type	Subject Code	Course Title	Credits	Sessional Marks				ESM	Total marks
				(L-T-P)	MSE	TA	Lab.	Total		
1	BSC	BCY252	Modern Analytical Techniques	4 [3-0-2]	15	20	15	50	50	100
2	ESC	BMA252	Computer Oriented Numerical Methods	4 [2-1-2]	15	20	15	50	50	100
3	PCC	TCH 252	Chemical Engineering Thermodynamics I	3 [2-1-0]	30	20		50	50	100
4	PCC	TCH 254	Mass Transfer Operations I	5 [3-1-2]	15	20	15	50	50	100
5	PCC	TCH 256	Chemical Process Utilities	3 [2-1-0]	30	20	-	50	50	100
6	HSMC	HHS 252	Engineering Economics & Management	3[3-0-0]	30	20	-	50	50	100
7	MC (Non Credit)	HHS 256	Indian Constitution	0[2-0-0]	30	20	-	50	50	100
Total Credits				**22**						

Year III, Semester-V

Sl. No.	Course Type	Subject Code	Course Title	Credits	Sessional Marks				ESM	Total marks
				(L-T-P)	MSE	TA	Lab.	Total		
1	PCC	TCH 351	Computer Aided Equipment Design	4 [2-1-2]	15	20	15	50	50	100
2	PCC	TCH 353	Chemical Reaction Engineering I	4 [2-1-2]	15	20	15	50	50	100
3	PCC	TCH 355	Mass Transfer Operations II	5 [3-1-2]	15	20	15	50	50	100
4	PCC	TCH 357	Chemical Engineering Thermodynamics II	3 [2-1-0]	30	20	-	50	50	100
5	PCC	TCH 359	Chemical Technology	3 [3-1-0]	30	20	-	50	50	100
6	OEC (Humanities)	HHS351	Entrepreneurship Development	3[3-0-0]	30	20	-	50	50	100
Total Credits				**22**						

Year III, Semester-VI

Sl. No.	Course Type	Subject Code	Course Title	Credits	Sessional Marks				ESM	Total marks
				(L-T-P)	MSE	TA	Lab.	Total		
1	PCC	TCH 352	Chemical Reaction Engineering II	4 [3-1-0]	30	20	-	50	50	100
2	PCC	TCH 354	Process Control & Instrumentation	4 [3-1-2]	15	20	15	50	50	100
3	PCC	TCH 356	Plant Design and Economics	3 [2-1-0]	30	20	-	50	50	100
4	PCC	TCH 358	Transport Phenomena	3 [2-1-0]	30	20	-	50	50	100
5	PCC	TCH 360	Plant Safety and Environmental Aspects	3 [2-1-0]	30	20	-	50	50	100
6	PCC	TCH 362	Material Science & Engineering	2[3-0-0]	30	20	-	50	50	100
7	OEC (Maths)	BMA352	Operation Research	3[3-0-0]	30	20	-	50	50	100
Total Credits				**22**						

Year IV, Semester-VII

Sl. No.	Course Type	Course Code	Subject	Credit	Sessional Marks				Sem. Final Exam.	Subject Total
				C [L-T-P]	MSE	TA	Lab.	Total		
1	PCC	TCH 471	Process Modeling and Simulation	5 [2-1-2]	15	20	15	50	50	100
2	PEC	TCH 453 – 459	Elective-I	3 [3-0-0]	30	20	-	50	50	100
3	PEC	TCH 461-467	Elective II	3 [3-0-0]	30	20	-	50	50	100
4	OEC	OCH 433	Open Elective I	3 [3-0-0]	30	20	-	50	50	100
5	PCC	TCH 495	Seminar	2 [0-0-4]	-	50	-	50	50	100
6	PCC	TCH 493	Industrial Report	2 [0-0-4]	-	50	-	50	50	100
7	PCC	TCH 497	Project	4 [0-0-8]	-	50	-	50	50	100
Total Credits				**22**						

Year IV, Semester-VIII

Sl. No.	Course Type	Course Code	Subject	Credit	Sessional Marks				Sem. Final Exam.	Subject Total
					MSE	TA	Lab.	Total		
1	PEC	TCH 452-458	Elective-III	4 [3-1-0]	30	20	-	50	50	100
2	PEC	TCH 460-466	Elective-IV	4 [3-1-0]	30	20	-	50	50	100
3	PCC	OCH 446	Open Elective -II	4 [3-1-0]	30	20	-	50	50	100
4	PCC	TCH 498	Project	10 [0-0-20]	-	50	-	50	50*	100
Total Credits				**22**						

LIST OF ELECTIVES

Open Elective-I [3-0-0]

OCH 433 Energy Resources and Utilization

Open Elective-II [3-1-0]

OCH 446 Air Pollution Monitoring and Control

Elective-I [3-0-0]

TCH 453 Nano Technology
TCH 455 Colloids & Interface Science and Engineering
TCH 457 Corrosion Science and Engineering
TCH 459 Electrochemical Technology

Elective-II [3-0-0]

TCH 461 Petroleum Refining & Petrochemical Technology
TCH 463 Principles of Polymer Engineering
TCH 465 Bio-System Process
TCH 467 Management of R&D

Elective-III [3-1-0]

TCH 452	Optimization : Theory and Practices
TCH 454	Advanced Chemical Process Control
TCH 456	Mathematical Methods in Chemical Engineering
TCH 458	Statistical Design of Experiments

Elective-IV [3-1-0]

TCH 460	Advanced Separation Processes
TCH 462	Conceptual Design of Chemical Processes
TCH 464	Energy Resources & Energy Conservation
TCH 466	Industrial Pollution Control and Waste Management

II B.Tech. Chemical Engineering Semester-III

TCH-251 CHEMICAL ENGINEERING FLUID MECHANICS

L	T	P	C
3	**1**	**2**	**5**

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objectives:

The objective of this course is to introduce the mechanics of fluids (fluid statics and fluid dynamics), relevant to chemical engineering operations. The course will introduce students to forces on fluids, hydrostatic forces on submerged bodies, Eulerian and Lagrangian descriptions of flow, flow visualization, integral analysis involving mass and momentum balances, Bernoulli equation, flow through pipes and ducts, flow measurement and instruments, flow transportation - pumps, blowers and compressors, conservation of mass, linear and angular momentum in differential form, Navier-Stokes equation, viscous flows, skin and form friction, lubrication approximation, potential flows and boundary layer theory. Turbulence and turbulent flows will be introduced.

Course outcomes:

Students completing the course will be able to

CO 1.	Describe basic concepts pertaining to fluids and fluid flow	Understand
CO 2	Analyze and apply fundamental principles of fluid dynamics, including flow characteristics, continuity, energy and momentum conservation	Analyze, Apply
CO 3.	Calculate Boundary layer thicknesses, friction factor, pressure drop, power requirements in single phase flow in pipes for fully developed laminar and turbulent flows.	Analyze, Evaluate
CO 4	Compare and select suitable device for flow measurement in open and closed channels and troubleshoot any problems in flow meters.	Analyze, Evaluate
CO 5.	Select a pump type and pump size to meet the specific pumping requirements	Understand, Evaluate
CO6	Conduct various experiments to apply the concepts of fluid mechanics	Apply

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PS
CO1	3	3												3	
CO2	3	3	3	3											
CO3	3	3	3	3	2							2	3	3	
CO4	3	3	3	2	2							2	3	3	1
CO5	3	3	3	3	3							2	3	3	
CO6	3							2	3	3		2	3	3	1
Average	3	3	3	2.75	2.333333333			2	3	3		2	3	3	1

Module 1 (8 hours)

Introduction: Types of fluids: Newtonian & non-Newtonian fluids, Compressible & incompressible fluids, Physical properties: Viscosity, Vapor pressure, Compressibility and Bulk modulus, Surface tension, Capillarity, Surface Tension. Fluid statics: Pascal's law for pressure at a point in a fluid, Variation of pressure in a Static fluid, Absolute, gauge pressure & vacuum, Pressure Measurement: Barometers, Piezo meters, Manometers: Simple U-tube manometer, Inverted U-tube manometer, Manometer with one leg enlarged, Two-fluid U-tube manometer, Inclined U-tube manometer, Pressure gauges and buoyancy.

Module 2 (6 hours)

Fluid flow: Stream line, Stream tube, Steady & Uniform flows, One-dimensional & multidimensional flow, Equation of continuity, Energy equation - Bernoulli's equation, Momentum equation, Navier Stokes equation, Water Hammer, Laminar and Turbulent flow, Compressible fluid flow, Two dimensional flow: Velocity potential, Potential function & Irrotational flow.

Module 3 (6 hours)

Boundary layer concepts: Introduction Development of boundary layer for flow over a flat plate Development of boundary layer for flow through circular pipe, entry length, fully developed flow. Boundary layer separation, flow of incompressible fluid in pipes: Laminar flow, Hagen Poiseuille equation, Friction factor, Pressure drop in turbulent flow, Velocity Distribution for turbulent flow, Surface roughness. Flow through non-circular pipes, Flow through curved pipes Expansion losses, Contraction losses, Losses for flow through fittings. Equivalent length of pipe fittings, Design of piping network.

Module 4 (5 hours)

Closed channel flow measurement: Venturimeter, Orifice meter, Venturi-Orifice Comparison, Pitot tube, Rotameter, Flow measurement based on Doppler effect, Hot wire and hot film anemometer, Magnetic flow meter, Open channel flow measurement: Elementary theory of weirs and notches.

Module 5 (5 hours)

Transportation of fluids: Pump classifications: suction, discharge, net pressure heads, specific speed and power calculations. NPSH, characteristics and constructional details of centrifugal pumps, Cavitation, Priming, Positive displacement pumps: Piston pumps –single and double acting Plunger pumps, Diaphragm pump, Rotary pumps, Gear pumps, Lobe pumps Screw pumps, Airlift pump, Jet pump. Selection of pumps, compressors types and operation, fans and blowers.

List of Experiments

1. To Verify Bernoulli's Theorem
2. To calculate friction loss in various pipe fittings

3. To calibrate Venturimeter and calculate its discharge coefficient
4. To calibrate orifice meter and calculate its discharge coefficient
5. To study and caliberation of Rotameter
6. To calculate Drag coefficient of solid sphere in the liquids of different viscosities
7. To calculate equivalent length of various pipe fittings
8. To study Reynolds experiment

Suggested Text Books

1. McCabe and Smith, Unit Operations of Chemical Engineering: McGraw Hill.
2. Coulson & Richardson, Chemical Engineering Vol. I: Pergamon, 1979 McGraw Hill.
3. Gupta, Vijay and S. K. Gupta, "Fluid Mechanics and its Applications", Wiley Eastern, New Delhi (1984).
4. Rajput, R. K., "Text Book of Fluid Mechanics", S. Chand and Co., New Delhi (1998).
5. Jain, A. K., "Fluid Mechanics including Hydraulic Machines", Khanna Publishers, Delhi (2007).
6. Bansal, R. K., "Fluid Mechanics and Hydraulic Machines", Laxmi Publications (P) Ltd., New Delhi (2005).

Suggested Reference Books

7. R. W. Fox, P. J. Pritchard and A. T. McDonald, Introduction to Fluid Mechanics, 7th Edition, Wiley-India 2010.
8. R. B. Bird, W. E. Stewart and E. N. Lightfoot, Transport Phenomena, 2nd Edition, Wiley India 2002.

TCH-253 PARTICLE AND FLUID PARTICLE PROCESSING

L	T	P	C
3	0	2	3

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective:

Objective of this course is to introduce students to the numerous industrial operations dealing with the particulate solids, their handling in various unit operations, and those in which particle fluid interactions are important. The course addresses fundamentals of fluid-particle mechanics, such as the notion of drag, and builds on those fundamentals to develop design concepts for various industrial processes like packed bed operation, fluidized operations, sedimentation, filtration, separation of solids and fluids, etc.

Course outcomes:

Students completing the course will be able to

CO1	Particle size analysis of a mixture of particles containing particles of different sizes and shape.	Define, Understand, Analyze
CO2	Select the proper size reduction equipment and calculate the power required in size reduction.	Understand, Analyze, Evaluate
CO3	Select a suitable device for fluid-solid separation and calculate separation time, Calculate pressure drop across a bed of packed solids.	Understand, Analyze, Evaluate
CO4	Select suitable filtration equipment; design a thickener.	Understand, Analyze, Evaluate, Create
CO5	Understand about the storage, handling and conveying/ transporting of the solid material; Select and design an agitator or mixing equipment.	Understand, Analyze, Evaluate, Create
CO6	Conduct various experiments to apply the concepts of particle and fluid particle processing	Understand, Evaluate

CO-PO Correlation

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1	2	1			1	1			2	1	3	1
CO2	3	2	1	2	1			1	1			2	1	3	1
CO3	3	2	1	3	3			1	3	2		2	2	3	1
CO4	3	2	1	3	3			1	3	2		2	3	3	3
CO5	3	2	1	3	3			1	3	2		2	3	3	3
CO6	3			2				2	2	2		3	2	3	1
Average	3	2	1	2.5	2.2			1.16	2.16	2		2.16	2	3	1.67

Module 1 (6 hours)

Particle Technology: Particle shape, shape factor, sphericity, particle size, different ways of expression of particle size, mixed particles size analysis, specific surface of mixture of particles, number of particles in a mixture, Screens – ideal and actual screens, standard screens, effectiveness of screen, industrial screening equipments, motion of screen, grizzlies, gyratory screens, vibrating screens and trommels, Sub sieve analysis – Air permeability method, sedimentation and elutriation methods.

Module 2 (6 hours)

Size Reduction: Introduction – types of forces used for communition, criteria for communition, characteristics of communited products, laws of size reduction, work index, energy utilization, Methods of operating crushers – free crushing, choke feeding, open circuit grinding, closed circuit grinding, wet and dry grinding, Equipments for size reduction – Blake jaw crusher, gyratory crusher, smooth roll crusher, toothed roll crusher, impactor, attrition mill, ball mill, critical speed of ball mill, ultrafine grinders and cutters.

Module 3 (6 hours)

Flow of Fluid Past Immersed Bodies: Drag, drag coefficient, Pressure drop in a bed of solids– Kozeny – Carman equation, Burke- Plummer equation, Ergun equation, Fluidization - conditions for fluidization, minimum fluidization velocity, types of fluidization, applications of fluidization, slurry transport, pneumatic conveying.

Motion of Particles Through Fluids: Mechanics of particle motion, equation for one dimensional motion of particles through a fluid in gravitational and centrifugal field, terminal velocity, drag coefficient, motion of spherical particles in various regimes, criterion for settling regime, hindered settling, modification of equation for hindered settling, centrifugal separators, cyclones and hydro-cyclones.

Module 4 (6 hours)

Sedimentation: Batch settling test and its applications, Coe and Clevenger theory, Kynch theory, thickener design. Filtration: Classification of filtration, cake filtration, clarification, batch and continuous filtration, pressure and vacuum filtration, constant rate filtration and cake filtration, principles of cake filtration, characteristics of filter media, filter aids and its applications, industrial filters, sand filter, filter press, leaf filter, rotary drum filter, horizontal belt filter, bag filter, centrifugal filtration- suspended batch centrifuge.

Module 5 (6 hours)

Agitation and Mixing: Agitation equipment, Types of impellers–Propellers, Paddles and Turbines, Flow patterns in agitated vessels, Prevention of swirling, Standard turbine design, Power correlation and Power calculation, Mixing of solids, Various types of mixers and blenders Storage and Conveying of Solids: Storage of solids, Open and closed storage, Bulk and bin storage, Conveyors – Belt conveyors, Chain conveyor, Apron conveyor, Bucket conveyor, Screw conveyor.

List of Experiments

1. To perform differential and cumulative screen analysis
2. To calculate reduction ratio in Jaw crusher
3. To calculate efficiency of Jaw crusher
4. To calculate reduction ratio in crushing roll
5. To calculate efficiency of crushing roll
6. To calculate critical speed of Ball mill
7. To study settling characteristics of Calcium carbonate slurry
8. To calculate free settling velocity

Suggested Text books

1. McCabe and Smith, Unit Operations of Chemical Engineering, McGraw-Hill, Fifth edition, 1993

2. W. L. Badger and J. T. Banchero, Introduction to Chemical Engineering, McGraw-Hill, 1979

3. Coulson and Richardson's Chemical Engineering, Vol. 2, Butterworth-Heinemann, Fifth edition 2002.

Suggested Reference Books

1. Rhodes, M. J., Introduction to Particle Technology, 2nd edition, John Wiley, Chichester; New York, 2008.

2. Allen, T., Powder Sampling and Particle Size Determination, Elsevier, 2003.

3. Masuda, H., Higashitani, K., Yoshida, H., Powder Technology Handbook, CRC, Taylor and Francis, 2006.

TCH-255 PROCESS HEAT TRANSFER

Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
2	1	2	4

Course Objective:

To understand the fundamentals of heat transfer mechanisms in fluids and solids and their applications in various heat transfer equipment in process industries like double pipe and shell and tube heat exchangers, evaporators, condensers and reboilers.

Course outcomes:

Students completing the course will be able to

CO1	Calculate heat transfer for one-dimensional; steady and unsteady state conduction in solids using analytical methods. Study and determination of heat rate through composite assemblies.	Analyze, Evaluate
CO2	Evaluate heat-transfer by free and forced convection for laminar and turbulent flows in internal configuration by employing basics of boundary layer concept and empirical correlations. Determination of heat rate through simple geometries under natural and forced convection.	Analyze, Evaluate
CO3	Understand different laws associated with radiation; Radiation heat transfer study and radiation between black bodies and gray bodies.	Understand, Analyze, Evaluate
CO4	Understand phase-change phenomena and latent heat of vaporization including free convection, nucleate and film boiling as well as drop-wise and film wise condensation. Process design of single effect evaporators and condensors.	Understand, Analyze
CO5	Understanding different types of heat exchangers. Utilizing phenomenon of log-mean temperature difference, over-all heat transfer coefficient. Preliminary sizing and selection of heat exchangers in design.	Understand, Analyze, Evaluate
CO6	Conduct various experiments to apply the concepts of heat transfer	Evaluate

CO-PO Correlation

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	2								1	1	3	
CO2	3	3	2	2								1	1	3	
CO3	3	3	2	2								1	1	3	
CO4	3	3	2	2								1	1	3	
CO5	3	3	2	2								1	1	3	
CO6	3			2				2	2	2		3	2	3	
Average	3	3	2	2				2	2	2		1.33	1.167	3	

Module 1 (7 hours)

Basic Concepts: Modes of heat transfer, conduction, convection and radiation, analogy between heat flow and electrical flow. Conduction: One dimensional steady state heat conduction, the Fourier heat conduction equation, conduction through plane wall, conduction through cylindrical wall, spherical wall, variable thermal conductivity, combined mechanism of heat transfer (conduction-convection-radiation systems), conduction through composite slab, cylinder and sphere, critical radius of insulation, Extended surfaces: heat transfer from a fin, fin effectiveness and efficiency, Introduction to unsteady state heat conduction.

Module 2 (6 hours)

Convection: The convective heat transfer coefficient, thermal boundary layers for the cases of flow of fluid over a flat plate and flow through pipe, dimensionless numbers in heat transfer and their significance, dimensional analysis, Buckingham's pi theorem, application of dimensional analysis to forced convection. Correlation equations for heat transfer in laminar and turbulent flows in circular tube and duct, Reynolds and Colburn analogies between momentum and heat transfer, heat transfer to liquid metals. Natural Convection: Natural convection from vertical and horizontal surfaces, Grashof and Rayleigh numbers.

Module 3 (4 hours)

Heat transfer by radiation: Basic Concepts of radiation from surface : black body radiation, Planks law, Wien's displacement law, Stefan Boltzmann's law, Kirchhoff's law, grey body, Radiation intensity of black body, View factor, emissivity, radiation between black surfaces and grey surfaces. Solar radiations, combined heat transfer coefficients by convection and radiation.

Module 4 (7 hours)

Boiling and Condensation: Pool boiling, pool boiling curve for water, maximum and minimum heat fluxes, correlations for nucleate and film pool boiling, drop wise and film wise condensation, Nusselt analysis for laminar film wise condensation on a vertical plate. Evaporation: Types of evaporators, boiling point elevation and Duhring's rule, material and energy balances for single effect evaporator, multiple effect evaporators: forward, mixed and backward feeds, capacity and economy of evaporators

Module 5 (6 hours)

Heat Exchangers: Types of heat exchangers, Principal Components of a Concentric tube & Shell and Tube Heat Exchanger, Baffles, Tubes and Tube Distribution, Tubes to Tube sheets Joint, Heat Exchangers with Multiple Shell & tube Passes, Fixed-Tube sheet and Removable-

Bundle Heat Exchangers, log-mean temperature difference, overall heat transfer coefficient, fouling factors, Design of double pipe heat exchangers. Preliminary sizing and appropriate selection of the heat exchangers in the design process.

List of experiments

1) Heat transfer through composite wall assembly
2) Heat flow rate through a lagged pipe
3) Heat transfer from a vertical cylinder under natural convection
4) Heat transfer by forced convection inside a horizontal pipe
5) Heat transfer from pin fin
6) Study of heat pipe
7) Determination of Stefan Boltzmann constant for radiation heat transfer
8) Study of a double pipe heat exchanger

Suggested Text Books

1. ”Heat transfer principles and applications” Dutta, B.K., PHI
2. “Heat Transfer” Holman J.P., 9th Ed., McGraw Hill.
3. “Chemical Engineering: Vol-1”, Coulson, J. M. & Richardson, J. F., 6th ed. Butterworth Heinemann

Suggested reference Books

1. “Principles of Heat Transfer”, Kreith F. and Bohn M., 6th Ed., Brooks Cole
2. “Process Heat Transfer”, Kern, D. Q McGraw Hill Book.
3. “Fundamentals of Heat and Mass Transfer”, Incropera F.P. and Dewitt D.P 5th Ed., John Wiley.

TCH-257 CHEMICAL PROCESS CALCULATIONS

L	T	P	C
2	1	0	3

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective:

To understand material and energy balance concepts and their applications in different unit operations and unit processes

Course Outcome

Students completing the course will be able to

CO 1	Understand fundamentals of gas law, vapor pressure, Psychrometric chart for application in material and energy balance	Understand, Analyze
CO 2	Appropriate basis and block diagram approach for solving material and energy balance problems.	Apply, Analyze
CO 3	Perform process calculations for material and energy balance in different unit operations	Apply, Analyze, Evaluate
CO 4	Perform process calculations for material and energy balance in different unit processes involving recycle and bypass too	Analyze, Evaluate
CO 5	Calculation of reaction or flame temperature using material and energy balance analysis	Understand, Apply, Evaluate

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	3	2	3	2				1	2		2	3	3	1
CO2	3	3	2	3	3				1	2		2	3	3	1
CO3	3	3	3	3	3				1	2		2	3	3	1
CO4	3	2	3	3	3				1	2		2	3	3	1
CO5	3	2	3	3	2				1	2		2	3	3	1
Avg	3	2.6	2.6	3	2.6				1	2		2	3	3	1

Module 1 (6 hours)

Units and dimensions, Conversion of units, Fundamental concepts of stoichiometry, Ideal gas law and its application.

Module 2 (6 hours)

Vapor pressure, Effect of temperature on vapor pressure, Vapor pressure plot, Raoult's Law, Solutions and phase behavior. Humidity and saturation, Use of humidity charts for calculations.

Module 3 (5 hours)

Material balances without chemical reaction, application of material balance in different unit operations, Introduction to unsteady state material balance.

Module 4 (5 hours)

Material balance with chemical reaction, bypass, recycle and purge operations

Module 5 (8 hours)

Components of energy balance equations, Heat capacities, Energy balance in Non flow and flow process, Effect of temperature on standard heat of reaction, Temperature of reaction.

Suggested Text books

1. Hougen, O.A., Watson, K.M and Ragatz, R.A., " Chemical Process Principles Part-I ", John Wiley and Asia Publishing, 1970.
2. Felder, R.M. & Rousseau, R.W. "Elementary Principles of Chemical Processes ", 3rd edition. JohnWiley. (1999)
3. K,V. Naraynan, B. Lakshmikutty "Stoichiometry and process calculations" 2nd edition PHI (2019)

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Suggested Reference Books

1. Himmelblau, D.M., "Basic Principles and Calculations in Chemical Engineering", sixth Edition, Prentice Hall Inc., 1996.

B. Tech. Chemical Engineering Semester-IV

TCH-252 CHEMICAL ENGINEERING THERMODYNAMICS -1

L	T	P	C
2	1	0	3

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective

Principles and application of first and second law of thermodynamics and Equation of State

Course Outcome

Students completing the course will be able to

CO 1	Explain basic concepts, laws and applications of thermodynamics.	Understand, Analyze
CO 2	Calculate changes in system properties and heat and work exchanged with the surrounding for open/close system using mass and energy.	Apply, Analyze, Evaluate
CO 3	Evaluate the volumetric properties of ideal and real gases.	Apply, Analyze, Evaluate
CO 4	Importance and Analysis of second law and calculation of ideal and lost work.	Analyze, Evaluate
CO 5	Solve problems involving liquefaction, refrigeration and different power cycles.	Understand, Apply, Evaluate

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	3	2	2								2			
CO2	3	3	3	3	3							2	3	3	
CO3	3	3	3	3	3							2	3	3	
CO4	3	3	3	3	3							2	3	3	
CO5	3	3	3	3	2							2	3	3	
Avg	3	3	2.8	2.8	2.75							2	3	3	

Module 1 (6 hours)

Introduction- scope of thermodynamics, Dimensions and Units, Temperature, Pressure, Work, Heat, Energy, Equilibrium, Phase rule, Joule's Experiment, Internal energy, Enthalpy, Heat capacities, Processes-Reversible & Irreversible, System & Surroundings.

Module 2 (6 hours)

Application of first law to closed & open systems like compressors, turbines, pumps, blowers, nozzles, diffuser, and throttle valves etc.

Module 3 (6 hours)

Introductory Concepts, Properties of Pure Substances, Phases, phase transitions, PVT behaviour; Ideal gas law, vander Waals, virial and cubic equations of state; Reduced conditions & corresponding states theories; correlations in description of material properties and behaviour

Module 4 (6 hours)

Introduction to Second Law of Thermodynamics, Statements of the Second Law of Thermodynamics, Perpetual Motion Machines; Reversible and Irreversible Processes, Factors for Irreversibility and Introduction to Reversible Cycles Carnot Theorem and Absolute Temperature Scale, Clausius Inequality and Introduction to Entropy, Thermodynamic Property Relationships; Entropy change for Solids, Liquids and Ideal gases, Entropy balance for Reversible and Irreversible Processes, Entropy Change in closed and open system,Calculation of ideal work, Lost work..

Module 5 (6 hours)

Thermodynamic analysis of steam power plants; Rankine cycle; Internal combustion engine, Otto engine; Diesel engine; Jet engine. The Carnot refrigerator; Vapour-compression cycle; Absorption refrigeration; Heat pump, Liquefaction processes

Suggested Text Books

1. "Introduction to Chemical Engineering Thermodynamics" by J.M. Smith and H.C. Van Ness, McGraw Hill International Ltd, 2005.

Suggested Reference Books

1. M J Moran, H N Shapiro, D D Boettner and M B Bailey, Principles of Engineering Thermodynamics, 8th Edition, Willey
2. Y Cengel and M Boles, Thermodynamics An Engineering Approach, 8^{th} Edition.
3. "Chemical Engineering Thermodynamics" by Y.V.C. Rao, Universities Press (India) Ltd. Hyderabad.
4. "Chemical and Process Thermodynamics", Kyle B.G., 3rd ed., Prentice Hall. 1999

TCH 254 MASS TRANSFER OPERATION-I

L	T	P	C
3	**1**	**2**	**5**

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objectives: To teach the students different separation techniques such as distillation, adsorption, liquid liquid extraction and solid liquid extraction

Course outcomes:

Students completing the course will be able to

CO 1	Explain the difference between flash, steam, batch and vacuum distillation and equilibrium considerations in distillation	Understand, Analyze
CO 2	Calculate the extent of separation achieved for continuous binary or multicomponent system	Apply, Analyze, Evaluate
CO 3	Evaluate liquid-liquid extraction and Calculate number of theoretical stages required for a given extent of separation by liquid-liquid	Apply, Analyze, Evaluate
CO 4	Evaluate solid-liquid and Calculate number of theoretical stages required for a given extent of separation by liquid-liquid or solid-liquid extraction for cross current and countercurrent flows	Analyze, Evaluate
CO 5	Calculate extent of adsorption for stage wise and continuous contact adsorption operations and evaluate ion exchange processes	Understand, Apply, Evaluate
CO6	Conduct various experiments to apply the concepts of mass transfer	Apply, Evaluate

CO-PO Correlation

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	2	3							2	2	3	1
CO2	3	3	3	2								2	2	3	1
CO3	3	3	3	2			1					2	2	3	1
CO4	3	3	3	2								2	2	3	1
CO5	3	3	3	2								2	2	3	1
CO6	3							2	3	3		2	2	3	1
Average	3	3	3	2	3		1	2	3	3		2	2	3	1

Module 1 (6 hours)

Distillation: Pressure-composition, Temperature-composition, Enthalpy-composition diagrams for ideal and non-ideal solutions; Raoult’s law and its application; Maximum and minimum boiling mixtures; Concept of relative volatility; Single Stage Distillation-Differential distillation, Flash vaporization; Vacuum and molecular distillations.

Module 2 (8 hours)

Introduction to Steam distillation, Continuous Distillation of Binary Mixtures: Multistage contact operations, Characteristics of multistage tower, McCabe-Thiele method, Ponchon-Savarit method, Concept of theoretical or ideal stage; Reflux ratio-maximum, minimum and optimum reflux ratio, Use of open steam, Tray efficiency, Determination of height and diameter of distillation column, Binary batch rectification with constant reflux and variable distillate composition, constant distillate composition and variable reflux; Principles of azeotropic and extractive distillation, Introduction to multi component distillation system.

Module3 (6 hours)

Liquid-Liquid Extraction: Applications; Ternary liquid-liquid equilibrium; Triangular graphical representation; Equipment used for single stage and multistage continuous operation; Analytical and graphical solution of single and multistage operation.

Module4 (5 hours)

Solid-Liquid Extraction: Applications; Solid-liquid equilibrium; Equipment used in solid liquid extraction; Single and multistage crosscurrent contact and countercurrent operations; Overall stage efficiency; Determination of number of stages.

Module5 (5 hours)

Adsorption: Description of adsorption processes and their application, Types of adsorptions, Nature of adsorbents; Adsorption isotherms and adsorption hysteresis; Stage wise and continuous contact adsorption operations, Determination of number of stages, Equipments; Ion exchange, Equilibrium relationship; Principle of ion-exchange, techniques and applications. Introduction to membrane separation processes.

Suggested Textbooks

1. Treybal, R.E. “Mass Transfer Operations”, 3rd ed. New York: McGraw-Hill, (1980).

Suggested Reference books

1. Sherwood, T. K., Pigford, R. L. and Wilke, C.R. “Mass Transfer” McGraw Hill (1975).
2. Geankoplis, C.J. “Transport Processes and Separation Process Principles”, 4th ed., PHI Learning Private Limited, New Delhi (2012).
3. Seader, J.D. and Henley, E.J., “Separation Process Principles”, 2nd ed., Wiley India Pvt. Ltd., New Delhi (2013).

LIST OF EXPERIMENTS

1. Determination of V-L-E diagram by measuring composition of binary and ternary components at different temperatures and vacuum levels apart from atmospheric pressure operation.
2. Verification of *Rayleigh equation* in a binary batch distillation process
3. To Study the performance of continuous distillation column.
4. Determination and Verification of yield of oil by steam distillation unit.
5. Determination of Liquid Equilibrium and construction of tie lines in triangular diagram
6. To Study the performance of solvent extraction packed bed or Rotating Disc Contactor (RDC).
7. Determination of efficiency and effect of one of the parameters on extraction in a micro channel.
8. Determination of efficiency and effect of one of the various parameters on the yield of oil in leaching.
9. Determination of efficiency and effect of one of the various parameters for removal of dissolved contaminant in water by adsorptive separation in activated carbon bed columns.
10. Determination of performance and efficiency of separation of membrane set up for removal of contaminants.

TCH 256 CHEMICAL PROCESS UTILITIES

L	T	P	C
2	1	0	3

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective: To learn about various utilities used in chemical process industries such as water, compressed air, vacuum, heating medium, steam, insulation and refrigerants. To make students familiar with the equipments used to generate, deliver and maintain these utilities namely boilers, compressors, blowers, vacuum pumps and air filters,

Course Outcomes

Students completing the course will be able to

CO1	Know the various process utilities and their importance in chemical plants, Water resources and water treatment for industrial use	Understand, Apply
CO2	Select a suitable process heating system for chemical plants; Design a steam generation and distribution system for a chemical plant	Understand, Apply, Evaluate
CO3	Handling and use of process heat transfer fluids	Understand, Apply, Evaluate
CO4	Select a proper insulator and insulation thickness for high, intermediate, low and sub zero temperature	Understand, Analyze, Evaluate, Apply
CO5	Select a suitable pressure and vaccum system and piping system under pressure or vacuum for chemical plants	Understand, Analyze, Evaluate, Apply

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	3	3	1	3		2	1	1	2	1	2	3	3	3
CO2	3	3	3	1	3	2	2	1	1	2	1	2	3	3	2
CO3	3	3	3	1	3		2	1	1	2	1	2	3	3	1
CO4	3	3	3	1	3	2	2	1	1	2	1	2	3	3	2
CO5	3	3	3	1	3	2	2	1	1	2	1	2	3	3	2
Avg	3	3	3	1	3	2	2	1	1	2	1	2	3	3	2

Module 1 (6 hours)

Utilities, their role and importance in chemical plants; Water- Sources of water and their characteristics; Requisites of industrial water and its uses; Methods of water treatment- Chemical softening, Demineralization; Resins used for water softening; Reverse osmosis and membrane separation; Effects of impure boiler feed water & its treatments-Scale & sludge formation, Corrosion, Priming & foaming, Caustic embrittlement; Reuse and conservation of water; Water resource management.

Module 2 (7 hours) Types of electrical process heating system- Dielectric heating, Resistance heating, Induction heating, Infrared heating, Properties of steam; Problems based on enthalpy calculation for wet steam, dry saturated steam, superheated steam; Steam generation, distribution and utilization; Types of steam generator / boilers: water tube & fire tube; Solid fuel fired boiler; Waste gas fired boiler; Waste heat boiler; Fluidized bed boiler; Scaling, trouble shooting, preparing boiler for Inspection; Design of efficient steam heating systems; steam economy, Steam condensers and condensate utilization, Expansion joints, flash tank design, Steam traps-Characteristics, selection and application.

Module 3 (6 hours)

Heat-transfer fluids: Heat-transfer fluid systems-Liquid-phase, vapour-phase systems; Heat-transfer fluids-Steam, synthetic organic fluids, Silicone fluids, Glycol-based fluids, Water, Paraffinic and mineral oils, Molten salts, Desirable properties of a heat-transfer fluid- Thermal properties, Containment properties, Stability properties, Fire safety, Environmental and toxicological properties, Selection of proper heat-transfer fluid-Liquid or vapour phase heat transfer, Maximum temperature, Minimum temperature, Vapour pressure, Thermal stability, Heat-transfer fluid degradation, Heat-transfer mist explosion.

Module 4 (5 hours)

Importance of thermal insulation for meeting the process requirement, Insulation materials and their effect on various materials of equipment, piping, fitting and valves etc., Insulation for high, intermediate, low and sub zero temperatures, including cryogenic insulation.

Module 5 (6 hours)

Pressure and Vacuum Systems: Compressors, blowers and vacuum pumps and their performance characteristics; Methods of developing vacuum and their limitations, material handling under vacuum, Piping systems; Lubrication and oil removal in compressors and pumps, Air filters, Air and gas leakage, Inert gas systems, Compressed air for process, Instrument air, Storage and Movement of Utilities within Plant.

Suggested Text Books

1. Nordell, Eskel, "Water Treatment for Industrial and Other Uses", Reinhold Publishing Corporation, New York.(1961).

2. P. L. Balleney, Thermal Engineering, Khanna Publisher, New Delhi

3. S. T. Powel, Industrial water treatment, McGraw Hill, New York
4. Chattopadhya, Boiler operations, Tata McGraw Hill, New Delhi
5. P. N. Ananthanarayan, Refrigeration & Air Conditioning, Tata McGraw Hill

Suggested Reference Books

1. Perry R. H. and Green D.W., Perry's Chemical Engineer's Handbook, McGraw Hill, New York
2. R. C. Patel and C. J. Karmchandani, Elements of Heat Engines Vol –II, III, Acharya Book Depot., Vadodara
3. Goodall, P. M., "The Efficient Use Of Steam" IPC Science and Technology (1980).

III B.Tech. Chemical Engineering Semester-V

TCH 351 COMPUTER AIDED EQUIPMENT DESIGN

Assessment

L	T	P	C
2	1	2	4

Sessional: 50 marks

End Semester: 50 marks

Course Objectives: The objective of this course is to acquire basic understanding of design parameters, complete knowledge of design procedures for commonly used process equipment and their attachments (e.g. internal and external pressure vessels, tall vessels, high pressure vessels, supports etc.), and different types of equipment testing methods.

Understand the basics of process equipment design and important parameters of equipment design.

Design internal pressure vessels and external pressure vessels.

Select standard piping, flanges, gaskets and bolts associated with the vessels and storage tanks

Design special vessels such as tall vessels and different supports for vessels.

Design liquid and gas storage tanks with and without floating roof.

Understand PFD & PI&D and different software tools used for designing

Conduct various numerical simulations to apply the concepts of computer aided equipment design

CO1	Understand the basics of process equipment design and important parameters of equipment design	Understand, Apply
CO2	Design internal pressure vessels and external pressure vessels.	Apply, Evaluate
CO3	Design special vessels such as tall vessels and different supports for vessels	Apply, Analyze, Evaluate
CO4	Design liquid and gas storage tanks with and without floating roof	Understand, Apply, Evaluate
CO5	Select standard piping, flanges, gaskets and bolts associated with the vessels and storage tanks	Understand
CO6	Conduct various numerical simulations to apply the concepts of computer aided equipment design	Apply, analyze

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO-1	3	3	1	1				1		1		2	2	3	1
CO-2	3	3	3	3				1		1		2	2	3	1
CO-3	3	3	3	3				1		1		3	2	3	1

CO-4	3	3	3	3				1		1		3	2	3	1
CO-5	3		1	1						1		3	2	3	1
CO-6	3			2	3			2	3	2		3	2	3	1
Avg	3	3	2.2	2.167	3			1.2	3	1.167		2.67	2	3	1

Module 1 (10 hours)

Introduction: Classification of engineering materials, properties of Ferrous metals, Non ferrous metals, alloys & Ceramic materials. Structure-Property relationship in materials. Deformation of Materials Fracture: Elastic deformation, Plastic deformation, Creep, Viscoelastic deformation, Different types of fracture, Corrosion and Prevention: Direct Corrosion, electro-chemical corrosion, Galvanic cells, High temperature corrosion, Passivity, factors influencing corrosion rate, Control of corrosion-modification of corrosive environment, Inhibitors, Cathodic protection, protective coatings. Corrosion charts, Metal forming techniques e.g. bending, Rolling, Forming & Metal joining techniques, welding – such as Butt, Lap, fillet, corner. Inspection and testing of process vessels.

Module 2 (8 hours)

Pressure Vessels: Type of pressure vessels, Thin cylinder theory for internal pressure. Code & standard for pressure vessels (IS:2825: 1969), Design considerations, classification of pressure vessels as per codes, design of cylindrical and spherical shells under internal and external pressure, selection and design of closures and heads such as Flat, hemispherical, torispherical, elliptical & conical; Introduction to compensation for opening such as nozzles & manholes etc.

Module 3 (8 hours)

Flanges: Selection of gaskets, selection of standard flanges, optimum selection of bolts for flanges, design of flanges. Inspection and testing of vessels, heads and flanges as per code specifications. Piping: Pipe thickness calculation under internal and external pressure, introduction to flexibility analysis of piping system. Tall Tower Design: Design of shell, skirt, bearing plate and anchor bolts for tall tower used at high wind and seismic conditions. Supports: Design of lug support and saddle support including bearing plates and anchor bolts.

Module 4 (7 hours)

Storage Tanks: Introduction to Indian standards, filling and breathing losses; Classification of storage tanks; Design of liquid and gas storage tanks with and without floating roof. High-pressure vessels, Fundamental equations, Mechanical design of centrifuges, Centrifugal pressure, Bowl and spindle motion: critical speed.

Module 5 (7 hours)

Introduction of various software used in chemical engineering equipment design, computer-based programming and designing of pressure vessel's shell and head. Types of process flow sheets: Process Flow Diagram (PFD), Process and Instrument Drawing (P&ID). Programming of calculation of centrifugal pressure, critical speed, pressure applied on storage vessel and computations for tall tower designs.

List of experiments

Application of computation tools, programming and simulation packages for the following,

1. Sizing and optimization of cylindrical vessels with heads.
2. Design of vessel shell under internal pressure.
3. Design of cylindrical vessel head under internal pressure.
4. Design of vessel under external pressure.
5. Design of flange and gasket.
6. Design of tall column shell for the top two sections.
7. Design of tall column for its complete height.
8. Design of shell of storage vessel.

Suggested Text Books

1. Brownell L. E. and Young E. H., "Process Equipment Design", Wiley, 2004.
2. Bhattacharya B. C., "Introduction of Chemical Equipment Design", CBS Publishers, 2003.
3. R.K.Sinnott, "Chemical Engineering Design Volume-6, 4/e", Elsevier Indian reprint, 2006 (Coulson & Richardson's Chemical Engineering Series).
4. I.S.:2825-1969, "Code for Unfired Pressure Vessels", Bureau of Indian Standards.1969 (Reaffirmed 1977)

Suggested Reference Books

1. Moss D. R., "Pressure Vessel Design Manual", 3rd Ed., Gulf Publishers.2004
2. Annartone D., "Pressure Vessel Design", Springer, 2007
3. M.V.Joshi "Process Equipment Design 2/e", Macmillan India, 1981(reprint 1985).

TCH 353 CHEMICAL REACTION ENGINEERING -I

L	T	P	C
2	**1**	**2**	**4**

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective: To apply knowledge from calculus, differential equations, thermodynamics, general chemistry, and material and energy balances to solve reactor design problems; To examine reaction rate data to determine rate laws, and to use them to design chemical reactors; To simulate several types of reactors in order to choose the most appropriate reactor for a given need; To design chemical reactors with associated cooling/heating equipment; To analyse Non-ideal flow behaviour in reactors.

Course Outcomes:

Students completing the course will be able to

CO1	Understand the basic concepts, involving reactions, rate equations and kinetic constants	Remember, Understand
CO2	Design single ideal reactors	Apply, Evaluate
CO3	Design multiple reactor systems and recycle reactor	Apply, Evaluate
CO4	Design for multiple reactions and non isothermal reactors	Apply, Evaluate, Analyze
CO5	Analyze non-ideal flow behavior in reactors	Apply, Evaluate, Analyze
CO6	Conduct various experiments to apply the concepts of chemical reaction engineering	Understand, Analyze, Create

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO
CO1	3	3	3	3	1	1	1				1	1	2	3	3
CO2	3	3	3	3	1	1	1				1	1	3	2	3
CO3	3	3	3	2							1	2	3	3	2
CO4	3	3	3	3							1	1	3	2	3
CO5	3	3	3	2							1	2	3	2	2
CO6	3			2				2	2	2		3	2	3	1
Avg	3	3	3	2.5	1	1	1	2	2	2	1	1.67	2.67	2.5	2.3

Module 1 (6 Hours)

Rate of Reaction, Elementary and non-elementary homogeneous reactions, Molecularity and order of reaction, Mechanism of reaction, Temperature dependency from thermodynamics, collision and activated complex theories. Integral and differential methods for analyzing kinetic data, Interpretation of constant volume reactor for zero, first, second and third order reactions, Half life period, Irreversible reaction in parallel and series, Catalytic reactions, Auto catalytic reactions, Reversible reactions.

Module 2 (5 Hours)

Interpretation of variable volume batch reactor data for zero, first and second order reactions, Space time and space velocity, Design equation for ideal batch, steady state continuous stirred tank, steady state plug flow reactors for isothermal reactions.

Module3 (6 Hours)

Design for single reactions, Size comparison of single reactors, Multiple reactor systems, plug flow/mixed flow reactors in series and parallel, Reactors of different types in series, Optimum reactor size, Recycle reactor, Autocatalytic reactions.

Module4 (7 Hours)

Introduction to multiple reactions, qualitative discussion about product distribution, quantitative treatment of product distribution and of reactor size, selectivity, the side entry reactor, irreversible first-order reactions in series, Quantitative treatment: plug flow or batch reactor, Quantitative treatment: mixed flow reactor, Heat of reaction from thermodynamics, Equilibrium constants from thermodynamics, General graphical design procedure for non-isothermal reactors, Optimum temperature progression, Heat effects: Adiabatic operations and non-adiabatic operations, Exothermic reactions in mixed flow reactors.

Module5 (6 Hours)

Residence time distribution of fluids in vessels, State of aggregation of the flowing systems, Earliness of mixing, Role of RTD, State of Aggregation and earliness of mixing in determining reactor behavior, E, F and C curves, Conversion in Non-ideal flow reactors.

Suggested Text Books

1. Levenspiel, O., “Chemical Reaction Engineering”, 3rd edition, John Wiley (1998).

Suggested Reference Books

1. Elements of Chemical Reaction Engineering by H. Scott Fogler, 6thEdition, Prentice Hall, 2021.

<u>List of Experiments</u>

1. To study the fundamental concepts of a batch reactor by operating it.

2. Understanding the working of CSTR concepts.
3. To study the fundamental concepts of a PFR by operating it.
4. To determine the rate law of saponification reaction by using a batch reactor.
5. To determine the activation energy of saponification reaction by using a batch reactor
6. To determine the rate law of saponification reaction by using a CSTR.
7. To determine the activation energy of saponification reaction by using a CSTR.
8. To determine the rate law of saponification reaction by using a PFR
9. To determine the activation energy of saponification reaction by using a PFR.

TCH 355 MASS TRANSFER OPERATIONS-II

L	T	P	C
3	**1**	**2**	**5**

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objectives:

The purpose of this course is to introduce the undergraduate students with the laws of diffusion; convective mass transfer, interface mass transfer and mass transfer coefficients, mass transfer correlations; mass transfer theories/models. This course will also provide proper understanding of unit operations such as absorption, drying, crystallization and humidification and dehumidification.

Course outcomes:

Students completing the course will be able to:

CO 1	Explain the principles of molecular diffusion and estimate rate of transfer by using diffusion coefficients for liquids and gases and experimentally measure the diffusivity of substances in gases and liquids	Define, Understand, Analyze, Evaluate, Create
CO 2	Analyze gas absorption and stripping systems for finding the stages or height of column & experimentally verify it on laboratory absorption/stripping setups	Define, Understand, Analyze, Evaluate, Create
CO 3	Perform calculations on humidification and dehumidification processes using psychometric chart and experimentally verify it on laboratory humidification and dehumidification setups.	Define, Understand, Analyze, Evaluate, Create
CO 4	Evaluate the batch drying data to design dryers and experimentally verify it on laboratory dryer setups	Define, Understand, Analyze, Evaluate, Create
CO 5	Evaluate the crystallization data to design the crystallizers and experimentally verify it on laboratory crystallization setups	Define, Understand, Analyze, Evaluate, Create
CO6	Conduct various experiments to apply the concepts of mass transfer	Apply Evaluate

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PS
CO1	3	3	3	3	2	2	2	1	2	3	2	3	3	3	2
CO2	3	3	3	3	2	2	2	1	2	3	2	3	3	3	2
CO3	3	3	3	3	2	2	2	1	2	3	2	3	3	3	2
CO4	3	3	3	3	2	2	2	1	2	3	2	3	3	3	2
CO5	3	3	3	3	2	2	2	1	2	3	2	3	3	3	2
CO6	3			2				2	2	2		3	2	3	1
Avg	3	3	3	2.83	2	2	2	1.16	2	2.83	2	3	2.83	3	1.83

Module 1 (10 hours)

Mass Transfer and Diffusion: Steady-state ordinary molecular diffusion: Fick's law of diffusion; Velocities in mass transfer, Equimolar counter diffusion; uni-molecular diffusion, Diffusion coefficients: Diffusivity in gas mixtures, diffusivity in liquid mixtures, Diffusivity in solids, One-dimensional, steady-state, molecular diffusion through stationary media, Mass transfer in turbulent flow: Reynolds analogy; Chilton-Colburn analogy; Other analogies, Models for mass transfer at a fluid-fluid interface: Film theory; Penetration theory; surface-renewal theory; film-penetration theory, Two-film theory and overall mass transfer coefficients

Module 2 (8 hours)

Absorption and Stripping: Equipments, Gas-liquid equilibrium, Henry's law, Selection of solvent, Absorption in tray column, Graphical and analytical methods, Absorption in packed columns, HTU, NTU & HETP concepts, Design equations for packed column.

Module 3 (8 hours)

Humidification and Dehumidification: Vapor-liquid equilibrium and enthalpy for a pure substance, Vapor pressure temperature curve, Vapor gas mixtures, Definition and derivations of relationships related with humidity, Fundamental concept of humidification, Dehumidification and Water cooling, Wet bulb temperature, Adiabatic and non-adiabatic operations, Evaporative cooling, Classification and design of cooling towers.

Module 4 (7 hours)

Drying: Solid-gas equilibrium, Different modes of drying operations, Definitions of moisture contents, Types of batch and continuous dryers, Rate of batch drying, Time of drying, Mechanism of batch drying, Continuous drying.

Module 5 (7 hours)

Crystallization: Crystal geometry-Crystal-size distribution; Thermodynamic considerations. Solubility and material balances, Enthalpy balance; Kinetic and transport considerations. Supersaturation, Nucleation, Crystal growth; Equipment for solution crystallization-Circulating, batch crystallizers, Continuous, cooling crystallizers, Continuous, vacuum evaporating crystallizers; MSMPR crystallization model-Crystal-population balance; Precipitation; Melt Crystallization-Equipment for melt crystallization; Zone melting.

Suggested Text Books

1. Treybal, R.E. "Mass Transfer Operations", 3rd ed. New York: McGraw-Hill, (1980).
2. B. K. Dutta, Principles of Mass Transfer and Separation Processes, 8th Printing, PHI Learning Private Limited, 2015

Suggested Reference Books

1. Sherwood, T. K., Pigford, R. L. and Wilke, C.R. "Mass Transfer" McGraw Hill (1975).
2. Geankoplis, C.J. "Transport Processes and Separation Process Principles", 4th ed., PHI Learning Private Limited, New Delhi (2012).
3. Seader, J.D. and Henley, E.J., "Separation Process Principles", 2nd ed., Wiley India Pvt. Ltd., New Delhi (2013).
4. A. S. Foust, Principles of Unit Operations, 2nd Ed., Wiley, 1980.
5. W. L. McCabe, J. C. Smith, P. Harriott, Unit Operations of Chemical Engineering, VII International edition 2005, McGraw-Hill.
6. Wankat P.C., Separation Process Engineering, Prentice Hall, III edition, 2011.

LIST OF EXPERIMENTS

1. Determination of diffusion coefficient of organic liquid vapor in air.
2. Determination of diffusion coefficient of naphthalene in fixed/fluidized bed.
3. Determination of diffusion coefficient of salt in liquid.
4. To evaluate the performance of gas liquid absorption in an absorption column.
5. To evaluate the performance of air stripping column.
6. To evaluate the performance of cooling tower.
7. To evaluate the performance of dehumidification column.
8. To plot the drying curves using moisture analyzer.
9. To evaluate the performance of a tray dryer.
10. To determine the yield of crystals in a crystallizer.

TCH 357 CHEMICAL ENGINEERING THERMODYNAMICS-II

L	T	P	C
2	1	0	3

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective:

To introduce the concepts of solution thermodynamics for application in phase and reaction equilibrium.

Course outcomes:

Students completing the course will be able to

CO 1	Calculate thermodynamic properties using residual properties and exergy analysis for simple systems	Define, Understand, Analyze, Evaluate
CO 2	Estimate the thermodynamic properties of substances in gas or liquid state of ideal and real mixture.	Define, Understand, Analyze, Evaluate,
CO 3	Evaluate dew point and bubble point for two-components and multi-components in Vapor-Liquid equilibrium.	Define, Understand, Analyze, Evaluate,
CO 4	Evaluate industrially important phase equilibrium processes.	Define, Understand, Analyze, Evaluate,
CO 5	Evaluate Gibbs free energy and analyze the effect of change in temperature, pressure and composition on equilibrium conversions of chemical reactions.	Define, Understand, Analyze, Evaluate,

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	3	3	3						1		2	3	3	1
CO2	3	3	3	3						1		2	3	3	1
CO3	3	3	3	3	3					1		2	3	3	1
CO4	3	3	3	3						1		2	3	3	1
CO5	3	3	3	3		1				1		2	3	3	1
Avg	3	3	3	3	3	1				1		2	3	3	1

Module 1 (6 hours)

First Law and second law, Exergy (Availability) and Exergy Analysis Thermodynamic properties of fluids: property relations for homogeneous phases, Maxwell relations, various equations of enthalpy, entropy and internal energy, Residual properties, two phase systems: Clapeyron equation.

Module 2 (6 hours)

Solution thermodynamics Theory: Fundamental property relation, Chemical potential and phase equilibrium, Partial properties, Ideal gas mixture model, fugacity and fugacity coefficient for pure species and in solution, Ideal solution model and excess properties

Module 3 (6 hours)

Phase Equilibria: Nature of equilibrium, phase rule, VLE qualitative behavior, Simple Models for VLE, VLE by Modified Raoult's law and VLE from K-value charts, UNIFAC and UNIQUAC models.

Module 4 (6 hours)

Solution thermodynamics Application: Liquid phase properties from VLE data, Models for the excess Gibbs energy, Property changes of mixing. Equilibrium and stability, Osmotic Equilibrium and osmotic pressure, liquid- liquid equilibrium and solid liquid equilibrium.

Module 5 (6 hours) The reaction coordinates, Application of the criteria for equilibrium to chemical reactions, the standard Gibbs free energy change and the equilibrium constant, effect temperature on equilibrium constant, evaluation of the equilibrium constants, Relation of equilibrium constants to composition, equilibrium conversions for reactions, phase rule for reacting systems

Suggested Text Books

1. Introduction to Chemical Engineering Thermodynamics by J.M. Smith and H.C. Van Ness, 7th ed., McGraw Hill International Ltd, 2005.

Suggested Reference Books

1. Chemical, Biochemical & Engineering Thermodynamics by S. Sandler. 4th Ed., John Wiley & sons, 2006.
2. Chemical Engineering Thermodynamics, by Narayanan, K.V., Prentice Hall. 2007.
3. Chemical and Process Thermodynamics Kyle B.G., 3rd ed., Prentice Hall. 1999.

TCH 359 CHEMICAL TECHNOLOGY

L	T	P	C
3	**1**	**0**	**3**

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objectives:

To study process technology, material requirements, production trends and conditions, preparation of process flow sheets, design aspects, engineering and environmental problems of various chemical industries.

Course outcomes:

Students completing the course will be able to

CO1	Identify different unit operations and unit processes in a given process flow diagram	Understand, Apply, Analyze, Evaluate, create
CO2	Demonstrate thorough understanding of some important process industries (chloro-alkali, fertilizers, urea, sulphur and phosphorous industry, industrial gases and cement industry, sugar manufacture, fermentation, Electro-chemical, Polymer and plastic industries etc.)	Understand, Analyze Evaluate
CO3	Make selection regarding raw material requirements, process conditions, and construction material and design aspects for the above-mentioned industries	Understand, Analyze, Evaluate
CO4	dentify and solve engineering problems during manufacturing of Apply, the above-mentioned products	Apply, Understand, Analyze
CO5	Identify process industry and make a presentation related to present scenario	Understand, Apply, Create

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	3	3	3	2	3	2	2	1	2	2	3	3	2	3
CO2	3	3	3	3	2	1	2	1	1	2	2	3	3	2	3
CO3	3	3	3	3	2	1	2	1	1	2	2	3	3	2	3
CO4	3	3	3	3	2		3	1	1	2	2	3	2	2	3
CO5	3	3	3	1	2		3	1	1	2	2	3	2	2	3
Avg	3	3	3	2.6	2	1.6	2.4	1.2	1	2	2	3	2.6	2	3

Module 1 (8 hours)

Introduction of chemical process industry with reference to Indian resources. Common salt, Caustic soda and Chlorine, Soda Ash, Hydrochloric acid, sulfuric acid, Phosphoric acid and super phosphates, Cement manufacturing.

Module 2 (7 hours)

Electrochemical industries, Industrial gases: Oxygen, Nitrogen, Hydrogen, Carbon dioxide, Synthesis gases.

Module 3 (10 hours)

Petroleum and Petrochemicals: Crude oil distillation, Thermal conversion processes (cracking, coking and visbreaking), Catalytic conversion processes (fluid catalytic cracking, catalytic reforming, hydro cracking, alkylation, isomerisation and polymerization), Petrochemicals Products (ethylene, propylene, formaldehyde, methanol).

Module 4 (7 hours)

Natural products industries: Sugar, Production of sugar from sugar cane, Glucose, Fermentation products such as Alcohol, Acetic acid, Citric acid.

Module 5 (8 hours)

Polymerization industries: Synthetic and natural fibers: Nylon, Dacron, natural and synthetic rubber, vulcanization and reclaiming of rubber, SBR, Thermosetting and Thermo Plastics (PVC, Polyethylene, Polyurethane, Teflon). Fertilizers: Ammonia, Nitric acid, Urea and other nitrogen fertilizers, mixed fertilizers.

Suggested Text Books

1. Rao, M.G., and Sittig, M., “Dryden's Outlines of Chemical Technology”, 3rd Edition, EWP East-West Press, 2010.
2. Austin G. T., “Shreve’s Chemical Process Industries”, 5th Edition, McGraw Hill, 2017.

Suggested Reference Books

1. Faith, W. L., Keyes, D. B. and Clark, R. L., “Industrial Chemicals” John Wiley.
2. Kirk and Othmer, "Encyclopaedia of Chemical Technology" Wiley, 2004.

III B.Tech. Chemical Engineering Semester-VI

TCH 352 CHEMICAL REACTION ENGINEERING-II

Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
3	**1**	**0**	**4**

Course Objective

Main purpose of this course is to introduce the basic concepts of heterogeneous reactions (fluid-fluid and fluid-solid) and develop rate equations considering mass transfer as well. This course will also focus on basic concepts of catalysis, kinetics and mechanistic aspects of catalysts and design and rating of catalytic reactors.

Course outcomes:

Students completing the course will be able to

CO1	Understand kinetics and design of fluid-fluid reactions	Apply, Evaluate
CO2	Understand kinetics and design of fluid-solid reactions	Apply, Evaluate
CO3	Explain methods for catalyst preparation, characterization, catalyst poisoning, mechanisms of catalytic reactions	Analyze, Evaluate
CO4	Design solid catalytic reactors	Apply, Analyze, Evaluate
CO5	Understand packed bed reactors and fluidized bed reactors	Understand, Analyze

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	3	3	3								1	3	2	1
CO2	3	3	3	3								1	3	2	1
CO3	3	3	3	3								1	2	1	1
CO4	3	3	3	3								1	3	2	2
CO5	3	3	3	3								1	3	2	1
Avg	3	3	3	3								1	2.8	1.8	1.2

Module 1 (10 hours)

Introduction to heterogeneous reactions, Fluid-fluid reactions: kinetics, the rate equation, The rate equation of straight mass transfer (Absorption) from gas to liquid, Rate equation for Mass Transfer and Reaction, Instantaneous reaction with respect to mass transfer- Different cases, Review of the Role of the Hatta modulus, Clues to Kinetic Regime from Solubility Data, Fluid-

fluid reactors Design: Factors to consider in selecting a contactor, Straight mass transfer - Plug Flow Gas/Plug Flow Liquid Countercurrent flow in a Tower, Mass Transfer along with not very slow reaction: Different cases.

Module 2 (8 hours)

Fluid-solid reactions: kinetics, Selection of a model, Progressive-conversion model, Shrinking-core Model, Comparison of Models with real situation, Shrinking core model for spherical particles of unchanging size, Diffusion through gas film controls, Diffusion through ash layer controls, Chemical reaction controls, Rate of reaction for shrinking spherical particles, Chemical reaction controls, film diffusion controls, Extensions, Particles of different shape, Combination of resistances, Limitations of shrinking core model, Determination of the rate controlling step, Fluid-particle reactors: Design, Particles of a single size, plug flow of solids, Uniform Gas composition, Mixture of particles of different but unchanging size, Plug flow of solids, Uniform gas composition, Mixed flow of particles of a Single Unchanging size, Uniform Gas Composition, Mixed flow of a size mixture of particles of Unchanging size, Uniform Gas Composition, Instantaneous Reactions.

Module 3 (8 hours)

Nature of catalysis, Adsorption isotherms, Physical properties of catalysts, preparation, testing and characterization of solid catalysts, catalyst selection, catalyst poisoning and mechanisms of catalytic reactions.

Module 4 (8 hours)

Reaction and diffusion within porous catalysts, effectiveness factor, heat effects during reaction, Experimental methods for finding rates, design of solid catalytic reactors.

Module 5 (6 hours)

Packed bed reactor, Staged Adiabatic Packed Bed Reactors, Staged Mixed Flow Reactors, Bubbling fluidized bed reactor, Hydrodynamic Flow Models, the K-L Model for Bubbling fluidized bed reactor.

Suggested Text Books

1. Levenspiel, O., “Chemical Reaction Engineering”, 3rd edition, John Wiley, (1998).
2. Smith, J, M, “Chemical Engineering Kinetics”, 3rd edition, McGraw-Hill (1990).

Suggested Reference Books

1. Chemical and Catalytic Reaction Engineering, Carberry, J. J., Dover Books on Chemistry, 2001.
2. Chemical Reactor Analysis and Design Gilbert F. Froment, Kenneth B. Bischoff, Juray De Wilde, John Wiley & Sons, Incorporated, 2010

TCH 354 PROCESS CONTROL AND INSTRUMENTATION

L	T	P	C
3	1	2	4

Assessment:

Sessional: 50 marks

End Semester:50 marks

Course Objective: Objective is to introduce the fundamentals of process control, controllers, stability and frequency response along with different process instruments used in chemical industries. The course will teach the students, how to obtain dynamic response of closed loop systems, stability analysis in transient and frequency domains. The course will also introduce about the instruments used for measurement of temperature, pressure, flow, level, viscosity.

CO1	Introduction to process control and controllers along with open and closed loop systems	Understand, Apply
CO2	Transient response of simple control systems	Apply, Evaluate, analyze
CO3	Concept of stability and frequency response, control system design by frequency response	Analyze, Evaluate, create
CO4	Understand the principles involved in measurements. knowledge on different measurement methods employed in industrial process units	Understand, Apply, Evaluate, analyze
CO5	Application of different measurement devices in Chemical Apply, evaluate , analyze industries	Apply, evaluate , analyze
CO6	Conduct various experiments to apply the concepts of instrumentation and control	Apply, evaluate

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	1	3									2	
CO2	3	3		3	3	1	3	3		3	1			3	2
CO3	3	2	3	3	3	2	3	3		3	2	3	3	3	3
CO4	3	3		3	3			1						1	1
CO5	3	3	3	2	3	2	2	3				1	3	3	3
CO6	3			2				2	2	2		3	2	3	1
Avg	3	2.8	3	2.33	3	1.67	2.67	2.4	2	2.7	1.5	2.3	2.67	2.5	2

Module 1 (8 hours)

Introduction to Process control systems, Use of Laplace & Inverse Laplace Transformation in study of Process Dynamics & Control. Dynamic behavior of First order system and First order systems in series. Second & higher order systems, Linearization of nonlinear systems, Transportation & Transfer Lag.

Module 2 (8 hours)

Classification of control systems, Regulator & Servo control, Feed Forward & Feed backward control, Negative & Positive Feedback Control, Modes of control action, Controllers & Final control Elements, Reduction of Block & Signal Flow Diagrams, and Transient response of simple control systems

Module 3 (8 hours)

Response of closed loop, Concept of stability, Stability Criterion, Routh test for stability, Introduction to frequency response, Introduction to control system design by frequency response (Bode Plot, Zeigler Nichols controller settings), Introduction to Controller Tuning.

Module 4 (8 hours)

Characteristics of measurement system, classification, performance characteristics, dynamic calibration, errors, statistical error analysis, Temperature measurement

Module 5 (8 hours)

Measurement of pressure: Manometers, Elastic pressure transducers, Measurement of Vacuum, Flow measurement, Level measurement, Density and viscosity measurement.

List of Experiments:

1. To calibrate and study the response of bimetallic thermometer.
2. To study the response of a liquid level tank system.
3. To calibrate the P/I converter.
4. To calibrate the given manometer for level measurement.
5. To determine the viscosity of given samples by constant stress rotational viscometer.
6. To study and calibrate diaphragm control valve.
7. To study the response of first order system in series using two tank liquid level system (Non-interacting system) to step input.
8. To study the response of first order system in series using two tank liquid level system (interacting system).
9. To calibrate a thermocouple using a glass bulb thermometer.
10. To assess the accuracy of a pressure gauge with a dead weight gauge tester.

Suggested Text Books

1. Coughnour and Koppel, “Process system Analysis and Control”, McGraw-Hill, New York, 1986
2. George Stephanopoulos, “Chemical Process Control”, Prentice-Hall of India Pvt Ltd., New Delhi, 1990
3. Singh, S.K., “Industrial Instrumentation and Control”, Prentice-Hall of India, 2016
4. Eckman, D.P., “Industrial Instrumentation” , Wiley eastern ltd., New York, 1990

Suggested Reference Books

1. P.K. Sarkar, “Process Dynamic and Control”, Prentice-Hall of India, 2014
2. D.N.Considine, “Process Instrumentation and Controls Books”, McGraw-Hill
3. Patranabis, “Principles of Industrial Instrumentation”, Tata Mcgraw Hill, 2008

TCH 356 PLANT DESIGN AND ECONOMICS

Assessment:

L	T	P	C
2	**1**	**0**	**3**

Sessional: 50 marks

End Semester: 50 marks

Course Objectives

The objective of this course is to acquire basic understanding of design parameters, complete knowledge of configuration and design procedures for commonly used process equipment in Heat transfer, Mass transfer and other operations. To gain the knowledge of cost and plant economics including depreciation, capital investment, cash flows, profitability evaluation and techno-economic feasibility

Course Outcomes:

Students completing the course will be able to

CO1	Analyze, synthesize and design processes for process heat exchangers	Analyze, Apply
CO2	Integrate and apply techniques and knowledge acquired in heat and mass transfer, fluid mechanics, instrumentation and control to design condensers, reboilers, jacketed and coiled vessels	Understand, Apply, Evaluate
CO3	Integrate and apply techniques and knowledge acquired to design distillation and packed column	Analyze, Evaluate, Apply
CO4	Undersanding capital investment and cash flow, estimation of operating and production cost for process plants	Evaluate, Analyze
CO5	Understanding depreciation, evaluating the profitability of process industry projects using different methods of profitability analysis, replacement costs; Optimizing production rates and evaluation of optimum conditions of operations	Understand, Evaluate, Apply

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PO12	PSO 1	PSO 2	PSO 3
CO1	3	3	3	3	3	3		1	2		1	2	3	3	1
CO2	3	3	3	3	3	3		1	2		1	2	3	3	1
CO3	3	3	3	3	3	3		1	2		1	2	3	3	1
CO4	3	3	3	3	2	2		1	3	1	1	3	2	1	
CO5	3	3	3	3	2	2		1	3	1	1	3	2	1	
Avg	3	3	3	3	2.6	2.6		1	2.4	1	1	2.4	2.6	2.2	1

Module 1 (6 hours)

Introduction , Basic design procedure and theory, Heat exchanger analysis: the effectiveness NTU method, Overall heat-transfer coefficient, Fouling factors (dirt factors), Shell and tube exchangers: construction details, Heat-exchanger standards and codes, Tubes, Shells, Tube-sheet layout (tube count), Shell types (passes), Shell and tube designation, Baffles, Support plates and tie rods, Tube sheets (plates), Shell and header nozzles (branches), Flow-induced tube vibrations, Mean temperature difference (temperature driving force), Shell and tube exchangers: general design considerations, Fluid allocation: shell or tubes, Shell and tube fluid velocities, Stream temperatures, Pressure drop, Fluid physical properties, Tube-side heat-transfer coefficient and pressure drop (single phase), Heat transfer, Tube-side pressure drop, Shell-side heat-transfer and pressure drop (single phase), Flow pattern, Design methods, Kern's method, Bell's method, Shell and bundle geometry, Effect of fouling on pressure drop, Pressure-drop limitations.

Module 2 (6 hours)

Condensers, Heat-transfer fundamentals, Condensation outside horizontal tubes, Condensation inside and outside vertical tubes, Condensation inside horizontal tubes, Condensation of steam, Mean temperature difference, Desuperheating and sub-cooling Condensation of mixtures Pressure drop in condensers, Design of forced-circulation reboilers, Design of thermosyphon reboilers, Design of kettle reboilers, Heat transfer to vessels, Jacketed vessels, Internal coils, Agitated vessels .

Module 3 (6 hours)

Design methods for binary distillation systems, Basic equations, McCabe-Thiele method, Low product concentrations, The Smoker equations, Batch distillation, Steam distillation, Plate efficiency, Prediction of plate efficiency. Approximate column sizing, Plate contactors, Selection of plate type, Plate construction, Plate hydraulic design, Plate-design procedure. Plate pressure drop, Downcomer design. Design of packed columns for absorption/stripping, Types of packing, Packed-bed height- Prediction of the height of a transfer unit (HTU), Prediction of the number of transfer units (NTU), Column diameter (capacity), Column internals, Wetting rates, Column auxiliaries.

Module 4 (6 hours)

Analysis of Cost Estimates: Factors affecting investment and production costs, Capital investment, Types of capital cost estimates, Methods for estimating capital investment, Estimation of Revenue, Introduction to cost and asset accounting, Cost indexes, Estimation of total product cost, Gross Profit, Net Profit and Cash flow Simple and Compound interest, Loan Payments, Annuities, Perpetuities and Capitalized cost. Cash flow pattern -Discrete cash flow & Continuous cash flow.

Module 5 (6 hours)

Depreciation: Straight line, Declining balance, Double declining balance, sum-of-the-digit, Sinking-fund, Accelerated cost recovery system, Modified accelerated cost recovery system, Profitability, Alternative investments by different profitability methods, Effect of inflation on profitability analysis, replacements, Taxes and insurance, Methods of profitability evaluation for replacements. Breakeven chart for production schedule, optimum production rate, optimum conditions in different operation, design report presentation, Techno-economic feasibility report.

Suggested Text Books

1. Sinnott R. K., "Chemical Engineering Design", Vol 6, Fourth Edition, Butterworth-Heinemann. 2006
2. Seader J. D. and Henley E. J., "Separation Process Principles", 2nd Ed., Wiley-India. 2006
3. I.S.: 4503-1967, "Indian Standard Specification for Shell and Tube Type Heat Exchangers", Bureau of Indian Standards. 2007
4. Peters M. S. and Timmerhaus K. D., "Plant Design and Economics For Chemical Engineers", 5th Ed., McGraw Hill, International Ed. 2004.

Suggested Reference Books

1. Ludwig E. E., "Applied Process Design for Chemical and Petrochemical Plants", Vol. 2, 3rd Ed., Gulf Publishers. 1997

TCH 358 TRANSPORT PHENOMENA

Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
2	1	0	3

Course Objectives

This course will highlight coupling between three transport phenomena with applications in various disciplines in engineering and science and will demonstrate to the students the common mathematical structure of transport problems. The course will deal with flow problems involving Newtonian and non-Newtonian fluids, solid-state heat conduction, convection, binary diffusion with or without chemical reaction.

Course Outcomes:

Students completing the course will be able to

CO1	Review of basic concepts of fluid mechanics and mathematics	Understand, Apply
CO2	Solve transport problems using shell balances	Apply, Evaluate
CO3	Formulate and solve one-dimensional transport problems by using the conservation equations	Apply, Analyze, Evaluate
CO4	Application of conservation equation in different known geometries Apply, Evaluate,	Understand, Evaluate, Create
CO5	Apply the shell balance, conservation equations and boundary conditions on different Systems	Understand, Evaluate, Create

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	2	2	1	1									2	
CO2	3	3	3	3	1									3	
CO3	3	3	3	3	1									3	
CO4	3	3	3	3	1									3	
CO5	3	3	3	3	1									3	
Avg	3	2.8	2.8	2.6	1									2.8	

Module 1 (6 hours)

Newton's law of viscosity, non –Newtonian fluids, pressure & temperature dependence of viscosity, estimation of viscosity from critical properties. Shell momentum balances, boundary conditions, flow of a falling film, flow through a circular tube, flow through annuals etc.

Module 2 (6 hours)

Time derivatives, The equation of continuity, the equation of motion, the equations of change in curvilinear, co-ordinates, use of the equations of change to set up steady flow problems.

Module 3 (6 hours)

Application of Equation of continuity and Navier stokes equation. Introduction to boundary layer theory and unsteady flow.

Module 4 (6 hours)

Fundamental laws of heat transfer, Conductivity and its dependence on temperature and pressure. Shell energy balances, Application in heat flow problems

Module 5 (6 hours)

Definitions of concentrations, velocities & mass fluxes, Fick's law of diffusion, Temperature & pressure dependence of mass diffusivity. Shell mass balance, boundary conditions, diffusion through a stagnant gas film. Diffusion with chemical reaction.

Suggested Text books

1. Bird, R. B., Stewart, W. E. and Lightfoot, E. N., "Transport Phenomena", 2nd edition John Wiley
2. Bannet, C. O. and Myers J. E., "Momentum Heat and Mass Transfer" Tata McGraw Hill

Suggested Reference Books

1. RS Brodkey and HC Hersey, "Transport Phenomena: A Unified approach", McGraw-Hill Book, (1988).

TCH 360 PLANT SAFETY AND ENVIRONMENTAL ASPECTS

L	T	P	C
2	1	0	3

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective: Study of Plant Safety is an essential requirement of the chemical process industries. Knowledge of plant safety is indispensable while working in plant to prevent accidents and damages. A safety management, audit and risk analysis skill prepares the plant operators and managers to emerge to a safe protocol and minimize potential damages to personnel, process equipment, and the environment. This course will give an overview of the safety regulations and practices, plant hazards and their control, risk management principles and techniques and accident analysis. The environmental aspects of various industries are also discussed to clear the comprehensive approach of the subject objective

CO1	Introduction and Identification of key concepts of safety, hazards, risk assessment and its management in process plant	Understand, Evaluate
CO2	Develop understanding of severity of incidents and importance of toxicological studies	Analyze, Remember
CO3	Understand and interpret a hazard and operability study (HAZOP) for the hazard identification, chances of occurring and consequences	Understand, Apply
CO4	Awareness about the various government/investigating agency such as EPA, OSHA, NSC for the analysis of safety related to environmental and human reliability	Remember, Apply
CO5	Demonstrate the root cause of the incident and study the plant safety based on environmental/technical aspects, and problems. Majorly in mineral, thermal power plant, metallurgical and petroleum industry, etc	Understand, Apply, Analyze

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	2	1	1	1	3	3	3	3	3	3	3	2	3	3
CO2	3	3	2	2	1	3	3	3	3	3	3	3	2	3	3
CO3	2	3	2	2	1	3	3	3	3	3	3	3	2	3	3
CO4	2	1				3	3	3	3	3	3	3		3	3
CO5	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3
Avg	2.6	2.4	2	2	1.25	3	3	3	3	3	3	3	2.25	3	3

Module 1 (5 Lectures)

Introduction, key concepts: Safety, Hazard, and Risk, Nature of the accident process, inherent safety. OSHA, fatal accident, fatality rate; Review of major chemical industry accidents: Flixborough Disaster, Seveso Disaster, Bhopal Disaster. Toxicological studies and TLVs.

Module 2 (8 Lectures)

Industrial Hygiene: Regulations, Identification, evaluation and control. Material safety data sheets. Introduction to source models. Fire triangle, flammability characteristics of liquids and vapor, estimation of flammability limits, LOC and inerting, Ignition energy, autoignition, autooxidation, adiabatic compression. Detonation and deflagration, VCE, BLEVE, Energy of a mechanical and chemical explosion. Inerting, vacuum and pressure purging, static electricity and its control. Explosion proof equipment and instruments.

Module 3 (7 Lectures)

Identification of reactive chemical hazards, relief concepts and types, relief systems. Introduction to relief sizing. Hazard Identification and Risk assessment, Hazard and Operability study (HAZOP); procedure and application. Probability theory and interaction between process units. Fault tree and event tree analysis;

Module 4 (4 Lectures)

Process safety strategies, managing safety, safety reviews and accident investigations, process uncertainties, reliability engineering and economics of loss prevention, designs for process safety.

Safety laws and regulations: Agencies involved as NFPA, OSHA, EPA and National Safety Council for safety management and environmental related issues.

Module 5 (6 Lectures)

Environmental aspects of plant safety: Environmental laws related to various industries. Protections against fire, explosions and toxic hazards; Process and plant safety; Introduction to safety audits.

Environmental health and safety guidelines: Occupational health and safety impacts of petroleum industry, coal processing, cement and lime, ceramic, fertilizer, textile, thermal power plant; metal, plastic and rubber industry.

Suggested Text Books:

1. Daniel A. Crowl and Joseph F. Louvar, Chemical Process Safety: Fundamentals with Applications, 3rd Edition, Pearson, 2014.
2. Lees' Loss Prevention in the Process Industries, 4th Edition, Butterworth-Heinemann, 2012.

Suggested Reference:

1. International Finance Corporation (World Bank Group): Environmental, Health, and Safety guidelines. (www.ifs.org)

TCH 362 MATERIALS SCIENCE AND ENGINEERING

L	T	P	C
3	0	0	3

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objectives: At the end of the course the student will have an understanding of science and engineering aspect of materials. The major focus shall be on the structure, properties, processing, and application of common as well as advanced engineering materials.

Course Outcomes:

Students completing the course will be able to

CO1	Materials selection, Structure & imperfections	Understand, Analyze
CO2	Corrosion, Structural & functional properties of materials	Understand, Analyze, Apply
CO3	Different engineering & advanced materials	Understand, Analyze, Apply
CO4	Different synthesis technologies & characterization of materials	Understand, Analyze, Apply
CO5	Economic & environmental issues, life cycle analysis	Understand, Apply, Evaluate

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	2	2	1	1	1	1				3	1	3	0	2	
CO2	3	2	3	1	3	2	2			2	1	3	2	2	
CO3	3	2	3	2	3	2	3			2	1	3	2	2	1
CO4	3	2	3	3	3		3			2	0	3	2	2	2
CO5	2	2	3	2	1	3	3	2		2	2	3	2	2	3
Avg	2.6	2	2.6	1.8	2.2	2	2.75	2		2.2	1	3	1.6	2	2

Module 1 (6 Lecture)

Historical perspective of Materials Science, Classes of engineering materials- engineering requirement of materials -selection of materials, Structure and Imperfections in Crystals: Crystal structure Crystal geometry, structure of solids, methods of determining structures. Imperfection in crystals - types of imperfection. Point imperfection, diffusion in solids - self diffusion Fick’s law, Applications of diffusion.

Module 2 (6 Lecture)

Properties and Corrosion of Material: Structural and Functional property, mechanical (Elastic and plastic properties), electrical and magnetic properties (Dia, para, Ferro, Antiferro and ferrimagnetism), Deformation of materials - corrosion, theories of corrosion, control and prevention of corrosion.

Module 3 (7Lecture)

Engineering materials - ferrous & non-ferrous metals - Metals and alloys, Iron and steel Iron carbon equilibrium diagram, Non-Metals: Inorganic materials: Ceramics, Glass and refractories - organic materials: wood, plastics, and rubber and wood, Advanced materials (Biomaterials, nanomaterials and composites) with special reference to the applications in chemical Industries.

Module 4 (7 Lecture)

Synthesis routes, Sol-gel technique, Nonaqueous Sol–gel route for Metal Oxide nanoparticles, hydrothermal synthesis, co-precipitation, preparation of nanocomposites, Characterization of Materials- Importance of Characterization of Materials, Structural and Functional Characterizations. Principles and application of different characterization techniques

Module 5 (4 Lecture)

Economic considerations, Environmental and societal considerations, Recycling issues, Life cycle analysis and its use in design.

Suggested Text Books:

1. William D. Callister, “Materials Science and Engineering”, 7th Edition, John Wiley & Sons, Inc
2. S.K. Hajra Choudhury, "Material Science and processes", 1st Edition, 1977. Indian Book Distribution Co., Calcutta

Suggested Reference Books:

1. Lawrence H. Van Vlack, Elements of Material Science and Engineering, 1971.
2. V. Raghavan, Materials Science and Engineering, Prentice Hall.

Final B.Tech. Chemical Engineering Semester-VII

TCH 471 PROCESS MODELING AND SIMULATION

L	T	P	C
3	1	2	5

Assessment:
Sessional: 50 marks
End Semester: 50 marks

Course Objectives

This course explores the basic concepts and steady state equations of simple systems in chemical process industries. It deals with the techniques for derivation of system model equations, data analysis and visualization. The basic objective is to develop the tools to analyze the system and to visualize the effect of various process inputs on system performance and state variables. The course aims to present the basic idea and concept on process model with detailed analysis and solution of model equations for steady and unsteady operation.

Course Outcomes:

Students completing the course will be able to

CO1	Model deterministic systems and differentiate between nonlinear and linear models	Remember, Understand
CO2	Numerically simulate linear and non-linear ordinary differential equations for deterministic systems	Understand, Apply
CO3	Estimate and validate a model based upon input and output data	Understand, Apply, Evaluate
CO4	Create a model prediction based upon new input and validate the output data	Understand, Analyze, Evaluate, Create
CO5	Develop steady state models for flash vessels, equilibrium staged processes, distillation columns, absorbers, strippers, CSTR, heat exchangers and packed bed reactors, Demonstrate the knowledge of various simulation packages and available numerical software libraries	Apply, Analyze, Evaluate,

CO6	Conduct various numerical simulations used in process modeling	Apply, Analyze, Evaluate

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1	2	2				1	2		2	1	2	
CO2	3	2	1	1	2				1	2		2	1	3	
CO3	3	3	2	1	3				1	2		2	2	3	
CO4	3	3	2	2	3				1	2		2	2	3	
CO5	3	3	3	3	3				2	2	1	2	2	3	
CO6	3			2	2			2	2	2		3	2	3	1
Avg	3	2.6	1.8	1.83	2.5			2	1.3	2	1	2.16	1.6	2.83	1

Module 1 (12 hours)

General introduction to numerical methods, Gauss elimination, Gauss Jordan, Gauss Seidel, SOR technique, secant method, Newton Raphson method, Runge Kutta method, Milne predictor corrector method, Introduction to mathematical modeling; Advantages and limitations of models and applications of process models of stand-alone unit operations and unit processes; Classification of models: Linear vs. Non-linear, Lumped parameter vs. Distributed parameter; Static vs. Dynamic, Continuous vs. Discrete, Stochastic vs Deterministic process; Numerical Methods: Iterative convergence methods, Numerical integration of ODE- IVP and ODE-BVP.

Module 2 (7 hours)

Concept of degree of freedom analysis: System and its subsystem, System interaction, Degree of freedom of a system e.g. Heat exchanger, Equilibrium still, Reversal of information flow, Design variable selection algorithm, Design variable reselection algorithm, Information flow through subsystems, Structural effects of design variable selection, Persistent Recycle.

Module 3 (7 hours)

Simple examples of process models; Models giving rise to nonlinear algebraic equation (NAE) systems, - steady state models of flash vessels, equilibrium staged processes distillation columns, absorbers, strippers, CSTR, heat exchangers, etc.; Review of solution procedures and available numerical software libraries.

Module 4 (7 hours)

Steady state models giving rise to differential algebraic equation (DAE) systems; Rate based approaches for staged processes; Modeling of differential contactors – distributed parameter models of packed beds; Packed bed reactors; Modeling of reactive separation processes;

Review of solution strategies for Differential Algebraic Equations (DAEs), Partial Differential Equations (PDEs), and available numerical software libraries. Introduction to unsteady state models and their applications.

Module 5 (7 hours)

Simulation and their approaches, Modular Sequential and Simultaneous approach, Equation solving approach, Simulation software and their applications, Review of solution techniques and available numerical software libraries. Review of thermodynamic procedures and physical property data banks.

Suggested Text Books

1. Luyben W.L., “Process Modeling, Simulation, and Control for Chemical Engineering”, 2nd Ed., Mc Graw Hill (1990).
2. D. F. Rudd and C. C. Watson, “Strategy of Process Engineering”, Wiley international.
3. M.M. Denn, “Process Modelling”, Wiley, New York, (1990).

Suggested Reference Books

1. A. K. Jana, “Chemical Process Modelling and Computer Simulation”, 2nd Ed., PHI, (2011)
2. C.D. Holland, “Fundamentals of Modelling Separation Processes”, Prentice Hall, (1975)
3. Hussain Asghar, “Chemical Process Simulation”, 1st Ed., Wiley Eastern Ltd., New Delhi, (1986)

<u>LIST OF EXPERIMENTS</u>

1. Solve a non-linear algebraic equation using Newton Raphson method.
2. Solve a differential equation using Runge Kutta method.
3. Calculate pressure drop in a pipe.
4. Calculate the minimum fluidization velocity.
5. Calculate the terminal velocity.
6. Solve a system of non-linear equations,
7. Calculate the molar volume of saturated liquid water and saturated water vapour using van der Waals, Redlich-Kwong and Peng-Robinson cubic equation of state.
8. Solve a system of simultaneous ordinary differential equations.
9. Solve for outlet temperatures in a series of stirred tanks with coil heater.
10. Solve for reactor height and conversion in a non-isothermal plug flow reactor (PFR).

11. Solve for concentration profiles of A, B and C in the series reaction A→B→C.

OPEN ELECTIVE - I

OCH 433 ENERGY RESOURCES AND UTILIZATION

Assessment:

L	T	P	C
3	0	0	3

Sessional: 50 marks

End Semester: 50 marks

Course Objective

To understand and analyze the present and future energy demand of the world and the nation and techniques to exploit the available renewable and non-renewable energy sources such as solar, bio fuels, wind energy, tidal energy, nuclear energy and energy from fossil fuels.

Course Outcomes

Students completing the course will be able to

CO1	Understand the energy demand and resources to fulfill the demand of the world and the nation.	Understand
CO2	Effectively utilize available renewable and non-renewable energy resources.	Understand, Apply
CO3	Explain modern energy conversion techniques.	Understand, Apply
CO4	Evaluate different energy technologies based on efficiency, impacts and other factors.	Understand, Apply, Analyze, Evaluate
CO5	Evaluate different ways to conserve energy in different contexts.	Apply, Analyze, Evaluate

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	2	1	1	1		1	3		1		2	2	3	1	2
CO2	2	2	3	1	1	1	3		1	1		2	1	1	2
CO3	2	2	2	2	1	3	3		2		2	2	2	2	2
CO4	1	2	2	2	1	2	3		1			2	2	2	2
CO5	2	2	3	1	1	2	3		2	1		2	3	2	3

Avg	1.8	1.8	2.2	1.4	1	1.8	3		1.4	1	2	2	2.2	1.6	2.2

Module 1 (6 hours)

Energy Scenario: Indian and global, energy crisis, Classification of various energy sources, Renewable and non-renewable energy sources, Remedial measures to some energy crisis. Energy Conservation: Biogas plants and their operation, Biomass and its conversion routes to gaseous and liquid fuels, Wind energy.

Module 2 (6 hours)

Fuel cell; Solar Energy: Photo thermal and photovoltaic conversion and utilization methods, Solar water heating, Solar cooking, Solar drying and its use for other industrial processes, solar cells: their material and mode of operation; Direct and indirect methods solar energy storage: Sensible heat and latent heat storage materials, Solar ponds; Bio energy: Biogas plants and their operations; Wind energy: its potential and generation by wind mills.

Module 3 (6 hours)

Hydroelectric potential: its utilization & production; Geothermal energy: its potential status and production; Nuclear energy: Status, Nuclear raw materials, Nuclear reactors and other classification, Generation of Nuclear power, Nuclear installations in India and their capacity of generation, Limitations of nuclear energy, Reprocessing of spent nuclear fuel; Cogeneration of fuel and power; Energy from tidal and ocean thermal sources; Magneto hydrodynamic power generation (MHD) systems.

Module 4 (6 hours)

Coal its origin and formation, Coal analysis, Coal classification, Coal preparation, Coal washing and Coal blending, Coal carbonization, Treatment of coal gas and recovery of chemical from coal tar, Coal gasification, liquid fuel synthesis from coal, Coal bed methane (CBM).

Module 5 (6 hours)

Petroleum crude, Types of crude, Emergence of petroleum products as energy, Gaseous Fuels: Natural gas, Water gas, Producer gas, LPG, Bio-gas, Coke oven gas, Blast furnace gas, LNG, CNG, Gas hydrates, GTL Technology (gas to liquid conversion), Biodiesel.

Suggested Text Books

1 Brame J.S.S. and King J.G., Edward Arnold "Fuel Solid, Liquid and Gases", 4^{th} Ed., Edward Arnold (1967).

Suggested Reference Books

1 Sukhatme S.P, "Solar Energy - Principles of Thermal Collection and Storage", 2nd Ed., Tata McGraw- Hill., (1996).

OPEN ELECTIVE - II

TCH 446 AIR POLLUTION MONITORING AND CONTROL

Assessment:

L	T	P	C
3	1	0	4

Sessional: 50 marks

End Semester: 50 marks

Course Objectives: To introduce various sources and classification of air pollutants. To understand various methods for air pollution monitoring and learn various dry and wet techniques for air pollution control at source.

Course Outcomes:

Students completing the course will be able to

CO1	Demonstrate comprehensive understanding of different types of air pollutants and various standards and acts regarding the air pollutants of global concern.	Understand, Apply
CO2	Select proper sampling and analysis method for a specific gaseous or particulate air pollutant.	Apply, Evaluate
CO3	Analyse plume behaviour and come up with a suitable stack design based on meteorological aspects of air pollution	Analyse, Evaluate
CO4	Select and design the most economical industrial dust collector for control of particulate emission at the source itself.	Apply, Evaluate
CO5	Design absorption columns for control of gaseous pollutants and three-way catalytic converters for pollution control from automobiles.	Apply, Evaluate

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	2	3	3	2		3	3		2			2	3	2	3
CO2	3	2	2	2		2	2		2		1	2	3	3	3
CO3	3	2	3	3	1	2	3		2			2	3	3	2
CO4	3	3	3	2	1	2	2		2		1	2	3	2	2
CO5	3	3	3	2	1	2	3		1		1	1	2	2	2
Avg	2.8	2.6	2.8	2.2	1	2.2	2.6		1.8		1	1.8	2.8	2.4	2.4

Module 1 (7 Lectures)

Air Pollutants - Sources and Classification, Effects of air pollutants on physical environment and living systems, Air pollution – Standards and acts, Global consideration of air pollution: Greenhouse effect, Chemical reactions in a contaminated atmosphere, urban air pollution, acid rain.

Module 2 (8 Lectures)

Air pollution monitoring, Sampling and analysis of gaseous and particulate air pollutants, Air pollution control by dilution of contaminants in atmosphere, Atmospheric stability, Lapse rate and Inversion, Meteorological aspects of air pollution: Dispersion models- Gaussian dispersion model, Plume behavior (Plume rise model), Stack design.

Module 3 (8 Lectures)

Air Pollution Control at Source - Source Correction methods - Particulate emission control: Dry techniques industrial dust collectors, cyclone and multiclone separators, bag filters, electrostatic precipitators, relative merits and demerits, choice of equipments, design aspects and economics.

Module 4 (9 Lectures)

Wet techniques for controlling particulate pollutants: wet dust collection, wet cyclone, empty scrubber, column (packed) scrubber, venturi scrubber, suitability, merits and demerits, design aspects and economics.

Module 5 (8 Lectures)

Techniques for Controlling Gaseous Pollutants: Absorption - absorbents and absorbers (plate towers and packed towers), Adsorption, Condensation - direct and contact, Combustion - Thermal, flare and catalytic. Pollution control from automobiles - three-way catalyst and catalytic converters.

Suggested Text Books:

1 Peavy H.S., Rowe D.R. and Tchobanoglous G., Environmental Engineering, McGraw-Hill edition, 1985

2 M.N. Rao and H.V.N. Rao, "Air Pollution", Tata McGraw Hill, New Delhi, 1993.

3 Rao C.S. "Environmental Pollution Control Engineering," 2nd Edition, New Age International Publishers, 2006.

Suggested Reference Books:

1 P. Sincero and G.A. Sincero Environmental Engineering: A Design Approach, Prentice Hall of India pvt Ltd, N. Delhi.1996

2 Y.B.G. Verma, H. Brauer," Air Pollution Control Equipments", Springer, Berlin, 1981

ELECTIVE I (TCH 453-459)

TCH 453 NANOTECHNOLOGY

L	T	P	C
3	**0**	**0**	**3**

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objectives

This course aims to provide a broad overview of fundamental principles and laws governing the properties at nanometer scale. Students will learn various top down and bottom up approaches for nanostructure synthesis and experimental techniques to characterize them. This course will also introduce various applications of nanotechnology in chemical engineering.

Course Outcomes:

Students completing the course will be able to

CO1	Describe the basic science behind the novel and superior properties of materials at the nanometer scale	Remember, Understand
CO2	Demonstrate a comprehensive understanding of the state-of-the-art nanofabrication methods	Understand, Apply
CO3	Compare and select suitable techniques for characterization of a given nanomaterial	Remember, Understand, Apply
CO4	Explain how nanotechnology can be put to use in varied areas of Apply, Analyze science and engineering	Apply, Analyze
CO5	Evaluate the impact of nanotechnology on society and environment. Evaluate current constraints such as regulatory, ethical, political, social and economic; when putting nanotechnology to use.	Understand, Apply, Analyze, Evaluate

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO2	2				2	2							2		
CO3	2				2	2							2		
CO4	2				2	2							2		
CO5	2				2	2							2		
Avg	2				2	2							2		

Module 1 (6 hours)

Introduction to Nanotechnology - its emergence and challenges, Nanomaterials and its classification, Properties of individual nanoparticles, Methods of synthesis, Reactivity of nanoparticles, List of stable carbon allotropes extended, Synthesis of carbon Bucky balls, Fullerenes, Metallofullerenes, solid C60, Bucky onions, Nanotubes, Nanowires, Nano cones, Carbon nanostructures, Graphene.

Module 2 (6 hours)

Methods of synthesis of Nanomaterials: Bottom-up (building from molecular level) and top-down (breakdown of bulk/microcrystalline materials) approaches. Manufacturing of nanoscale materials: Chemical vapor deposition of carbon nano tubes, Plasma deposition of ultra-thin functional films on Nano materials, Solution based Synthesis of Nanoparticles, Vapour Phase Synthesis & Synthesis with framework, Nanolithography, Dip Pen Lithography. Artificially Layered Materials: Quantum Well, Quantum Dots, Super lattices & Layered Structures, core shell nano structure.

Module 3 (6 hours)

Top down approach vs Bottom up approach, Optical Microscopy, Electron Microscopy, Secondary electron scattering, back scattering, Scanning Probe Microscopes, Focused Ion Beam Technique, X-ray imaging, Transmission Electron Microscope (TEM), Scanning Probe Microscope (SPM)- Atomic Force Microscope (AFM), Scanning Tunneling Microscope (STM).

Module 4 (6 hours)

Surface Tension and Interfacial Tension, Surfaces at Equilibrium, Surface Tension Measurement, Contact Angles, Colloidal Stability, Electrical Phenomena at Interfaces, Vander Waals

Forces between Colloidal Particles, Photo catalysis Nanostructured materials, Self-assembly and Catalysis.

Module 5 (6 hours)

Nano biotechnology : Drug Delivery, Nano clay, Nanocomposites, Surface coatings, Self-cleaning Materials, Hydrophobic Nanoparticles, Biological nanomaterials, Nano electronics, Nano machines & Nano devices, Nano hydrogel, Photocatalytic reactors, Nano clay Synthesis, Polymer nanocomposite, Waste Water Treatment, Societal, Health and Environmental Impacts, Introduction to industries which produces commercial nanomaterials.

Suggested Text Books

1. G. Louis Hornyak, Joydeep Dutta, Harry F. Tibbals and Anil K. Rao, Introduction to NanoScience, CRC Press of Taylor and Francis Group, 2008
2. Pools C.P. and Owens F.J., Introduction to Nanotechnology, Wiley-Interscience, 2003
3. G.Cao, Nanostructures and Nanomaterials, Synthesis, Properties and Applications, Imperial College Press, 2004.

Suggested Reference Books

1 Bhusan B., Springer Handbook of Nanotechnology, 4th Ed., 2017

TCH 455 COLLOIDS & INTERFACE SCIENCE AND ENGINEERING

Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
3	0	0	3

Course Objectives

To introduce the fundamentals of colloid and interface science; specifically the nature of various interparticle forces, how they can be calculated and applied. To understand the origins of surface tension, its measurement and how it can be modified by addition of surfactants. To understand factors determining colloidal stability and actual applications of colloidal phenomena in industries.

Course Outcome

On completion of this course, students will be able to

CO1	Explain the concepts of surface and interfacial energies and tensions and how they can be measured	remember, understand
CO2	Identify the nature of various interparticle forces between colloidal systems and how they can be calculated	remember, understand
CO3	Evaluate when stable emulsions will be formed using DLVO and DLVO like theories	analyze, evaluate
CO4	Select suitable surfactants for specific applications in nanofluids and advanced and functional materials	understand, apply, analyze
CO5	Identify the ways in which wettability of surfaces can be manipulated for preparing superhydrophobic surfaces	understand, apply

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	1								2	1	3	2	2	2
CO2	3	1	1	1						2	1	3	2	2	2
CO3	3	2	1	1						3	2	3	2	3	2
CO4	3	2	2	2	2		1		1	3	3	3	3	3	3
CO5	3	2	2	2	2		1		1	3	3	3	3	3	3
Avg	3	1.6	1.5	1.5	2		1		1	2.6	2	3	2.4	2.6	2.4

Module 1 (6 hours)

Effects of confinement and finite size, concepts of surface and interfacial energies and tensions, Apolar (van der Waals) and polar (acid-base) components of interfacial tensions. Young-Laplace equation of capillarity, examples of equilibrium surfaces, multiplicity, etc., Stability of equilibrium solutions, contact angle and Young's equation, Determination of aploar (van der Waals) and acid-base components of surface/interfacial tensions. Free energies of adhesion, kinetics of capillary and confined flow.

Module 2 (6 hours)

Intermolecular, nanoscale and interfacial forces in organic, polymeric, biological and aqueous systems, van der Waals, electrostatic double layer, acid-base interactions including hydrophobic attraction and hydration pressure

Module 3 (6 hours)

Gibb's treatment of interfaces, concept of excess concentration, variation of interfacial tension with surface concentration, Adhesion, wetting, nucleation, flotation, patterning of soft material by self-organization and other techniques.

Module 4 (6 hours)

DLVO and DLVO like theories and kinetics of coagulation plus general principles of diffusion in a potential field/Brownian movement.

Module 5 (6 hours)

Stability of thin (< 100 nm) film, self-organization in confined systems, mesoscale patterning. Superhydrophobicity, functional coatings, structural colours, nano-adhesives, nano-composites.

Suggested Text Books

1. Principles of Colloid and Surface Chemistry, Paul C. Hiemenz, Marcel Dekker, 2nd edition and onwards,1986.

2. Physical Chemistry of Surfaces, Arthur W. Adamson, 5th edition, Wiley,1990.

3. Foundations of Colloid Science, Robert J. Hunter, Clarendons, Oxford, Volume 1,1989.

4. Colloidal Dispersions, W. B. Russel, D. A. Saville, and W, R. Schowalter, Cambridge University Press,1989.

Suggested Reference Books

1. Intermolecular and Surface forces, Jacon N. Israelachvili, Academic Press, 1992 or later editions.

2. Interfacial Forces in Aqueous Media, Carel J. van Oss, Marcel Dekker or Taylor Francis, 1994.

TCH 457 CORROSION SCIENCE AND ENGINEERING

Assessment:

L	T	P	C
3	0	0	3

Sessional: 50 marks

End Semester: 50 marks

Course Objectives

This course introduces the principles of corrosion, common corrosion forms; the concept of corrosion measurement and monitoring methods, with a link to fundamental electrochemistry. Corrosion protection systems are discussed, with a broad overview of coating and surface treatment/engineering routes and material selection to reduce corrosion cost.

Course Outcome

On completion of this course, students will be able to

CO1	Explain the industrial applications and economic benefits of corrosion control	Remember, Understand
CO2	Evaluate if corrosion can occur under specific operating condi- tions in a given equipment or construction	Apply, Analyze, Evaluate
CO3	Determine the probable corrosion type, estimate the corrosion rate and propose the most reasonable protection method as re- gards safety, price and environmental considerations	Understand, Apply
CO4	Select proper material, design and operating conditions to reduce the likelihood of corrosion in a given equipment	Apply, Analyze, Evaluate
CO5	Perform troubleshooting and corrosion monitoring	Understand, Apply, Analyze, Evaluate, Create

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	2	1	1		2	3			2		2			
CO2	2	2	2	1	2					2		2			
CO3	3	2	2	3	3	3	2			1	2	2	2	2	2
CO4	3	2	2	2	2	2	2			1	1	2	2	2	2
CO5	3	2	2	2	3	1	2			2	2	2	2	2	2
Avg	2.8	2	1.8	1.8	2.5	2	2.25			1.6	1.67	2	2	2	2

Module 1 (6 hours)

Basic aspects, introduction, classification, economics and cost of corrosion. EMF series, Galvanic series, corrosion theories, derivation of potential-current relationship of activation controlled and diffusion corrosion processes. Potential-pH diagrams: General aspects, Potential-pH diagrams for specific metals; Fe-H_2O system, application and limitations. Passivation definition, anodic passivation, theory of passivation, oxidation laws, effects of oxygen and alloying on oxidation rates.

Module 2 (6 hours)

Forms of corrosion - definition, factors and control methods of various forms of corrosion such as pitting, intergranular, crevice, stress corrosion, corrosion fatigue, hydrogen embrittlement, corrosion processes and control methods in fertilizers, petrochemical and petroleum refineries

Module 3 (6 hours)

Environmental aspects: Atmospheric corrosion- classification, factors influencing atmospheric corrosion, temporary corrosion, preventive methods, corrosion in immersed condition, effect of dissolved gases, salts, pH, temperature and flow rates on corrosion, Underground corrosion-corrosion process in the soil, factors influencing soil corrosion.

Module 4 (6 hours)

Corrosion control aspects: Electrochemical methods of protection-theory of cathodic protection, design of cathodic protection, sacrificial anodes, anodic protection. Corrosion inhibitors for acidic, neutral and alkaline media, cooling water system-boiler water system. Organic coating-surface preparation, natural synthetic resin, paint formulation and applications. Design aspects in corrosion prevention, corrosion resistant materials.

Module 5 (6 hours)

Corrosion Testing, monitoring and inspection, laboratory corrosion tests, accelerated chemical tests for studying different forms of corrosion. Electrochemical methods of corrosion rate measurements by DC and AC methods, corrosion monitoring methods, chemical and electrochemical removal of corrosion products.

Suggested Text Books

1 S.N. Banerjee, An Introduction to Corrosion and Its Inhibition, Oxonian Press Ltd., New Delhi (1985).

2 LL Shrier Corrosion Vol. I & II George Nownons Ltd., Southhampton Street London, 2^{nd} Ed. (1976)

3 M.G. Fontana & N.D. Greene, Corrosion Engineering, 3^{rd} Ed., McGraw Hill, New York

4 H.H. Uhlig, Corrosion and Corrosion Control. A Wiley- Inter Science. Publication John Wiley & Sons, New York.

Suggested Reference Books

1 C.T. Munger - Organic Coatings

2 Jain & Jain, Engineering Chemistry, 17^{th} Ed., Dhanpat Rai & Sons, New Delhi (2022).

TCH 459 ELECTROCHEMICAL TECHNOLOGY

L	T	P	C
3	**0**	**0**	**3**

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objectives

This course introduces the principles of electrochemistry; the fundamentals of corrosion and related concepts, with a link to fundamental electrochemistry. Different methods of corrosion protection methods are discussed. Classification of electrochemistry processes are studied. Electrochemical reactors and electrodes used in industry are discussed.

Course Outcome

On completion of this course, students will be able to

CO1	Understand the basics of electrochemistry and the laws associated with it	Remember, Understand
CO2	Study the role of electrical double layer in electrochemical process	Remember, Analyze
CO3	Understand the fundamentals of corrosion and study the theories of corrosion. Illustrate the different methods of corrosion control and protection.	Understand, Apply, Evaluate
CO4	Study the classification and understanding the principles of electrochemistry process	Apply, Analyze
CO5	Know the types of electrodes and its use in industry Understanding the fundamentals of electrochemical reactors and knowing its applications	Understand, Apply, Analyze, Evaluate, Create

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	2	1							2		3			
CO2	2	2	1		2					2		3			
CO3	3	2	3	2	2	2	2			2	1	2	1	1	
CO4	2	2	1							2		3	2	2	
CO5	3	2	2	2			1			2		2		2	
Avg	2.6	2	1.6	2	2	2	1.5			2	1	2.6	1.5	1.66	

Module 1 (6 hours)

Review fundamentals of electrochemistry: Basic elements of electrochemistry, devices used in electrochemistry. Theories and laws related to electrochemistry: Faraday's law, Nernst potential, galvanic cells, polarography. The electrical double layer, it's role in electrochemical processes, electro capillary curve, Helmoltz layer, Guoy, Sterrn layer, fields at the interface.

Module 2 (6 hours)

Mass transfer in electrochemical systems, diffusion controlled electrochemical reaction, importance of convention and the concept of limiting current, over potential, primary, secondary current distribution, rotating disc electrode.

Module 3 (6 hours)

Introduction to corrosion, corrosion theories, derivation of potential, current relations of activities controlled and diffusion controlled corrosion process. Potential, pH diagram, forms of corrosion, definition, factors and control methods of various forms of corrosion, corrosion control measures, industrial boiler water corrosion control, protective coatings, vapour phase inhibitors, cathodic protection, sacrificial anodes, paint removers.

Module 4 (6 hours)

Electro deposition, electro refining, electroforming, electro polishing, anodizing, selective solar coatings, primary and secondary batteries, types of batteries, fuel cells.

Module 5 (6 hours)

Electrodes used in different electrochemical industries: Metals, Graphite, Lead dioxide, titanium substrate insoluble electrodes iron oxide, semi conducting type etc. Metal finishing, cell design- types of electrochemical reactors, merits of different type of electrochemical reactors.

Suggested Text Books

1. Picket, Electrochemical Engineering, Prentice Hall, 1977.
2. Newman, J.S., Electrochemical systems, Prentice Hall, 1973.
3. Barak, M. and Stevenge, U.K., Electrochemical Power Sources Primary and Secondary Batteries, 1980.
4. Mantell, C., Electrochemical Engineering, McGraw Hill, 1972.

Suggested Reference Books

1. Lenny Hart, Electrochemistry and Electrochemical Engineering, Library Press, 2018

ELECTIVE II (TCH 461-467)

TCH 461 PETROLEUM REFINING AND PETROCHEMICALS

Assessment:

L	T	P	C
3	0	0	3

Course Objectives:

Petroleum refining as well as petrochemical industries constitute a major part of chemical sector. Knowing the sources of crude petroleum, extraction of the crude petroleum, its refining to the useful petro-products and efficient transport to the end users through network are important tasks to the petroleum or chemical engineers. This course intends to form the foundation of the chemical engineers on basic fields of petroleum from extraction to the safe end use where refining is the most challenging. The course puts major thrust on all the techniques/processes of petroleum refining encompassing selection of the mass/heat transfer devices, their operation and basic design. The course also covers the feed stocks of petrochemical industries and manufacture important petrochemicals.

Course Outcomes:

Students completing the course will be able to

CO 1	Understanding the role of petroleum as energy source amidst world energy scenario	Understand, Apply
CO 2	Define various test properties of crude oil and petroleum products and also explain their physical significance	Understand, Analyze
CO 3	Explain crude oil processing, treatment techniques and cracking reactions taking place in a petroleum refinery	Apply, Analyze, Evaluate
CO 4	Apply acquired knowledge of refinery processing and manufacturing technologies of producing petrochemicals for problem solving	Understand, Apply
CO 5	Compare various routes of production of widely used petrochemicals	Understand, Analyze,

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	2	2					2					2	3		2
CO2	2	2											3	1	2
CO3	2	2				1							2		
CO4	2	3	3										3	2	
CO5	2	2											3		2
	2	2.2	3			1	2					2	2.8	1.5	2
Avg	2	2					2					2	3		2

MODULE 1:

Origin and occurrence, composition, classification and physio-chemical properties of petroleum; Distillation Characteristics such as TBP,ASTM & EFV etc.

MODULE 2:

Quality Control of Petroleum Products. Classification of laboratory tests, distillation, vapour pressure, flash and fire points, octane number, performance number, cetane number, aniline point, viscosity index, calorific value, smoke point, char value, viscosity, viscosity index, penetration tests, cloud and pour points, drop point of grease, melting and settling points of wax, softening point of Bitumen, induction period of gasoline.

Crude Oil Distillation: Desalting of crude oils, Atmospheric distillation of crude oil, Vacuum distillation of atmospheric residue.

MODULE 3:

Thermal Conversion Process: Thermal Cracking Reactions, Thermal Cracking, Visbreaking, Coking (Delayed Coking, Fluid Coking, Flexicoking), Calcination of Green Coke.

Catalytic Conversion Process: Fluid catalytic cracking; Catalytic reforming; Hydrocracking Catalytic Alkylation, Catalytic Isomerization; Catalytic Polymerization.

MODULE 4:

Petrochemical feed stocks;C1 and C2 Petrochemicals: Methanol, Formaldehyde, Chloromethane etc. Ethylene, Ethylene Dichloride, Vinyl Chloride, Ethylene Oxide, Ethylene Glycol, Ethanol amines etc.

MODULE 5:

C3, C4, Aromatics and Polymers: Propylene, Butadiene, etc.BTX Separation, p-xylene, Styrene, p-terephthalic acid, etc.PVC, LDPE, LLDPE, HDPE, Polypropylene, Polypropylene Copolymers , Polystyrene , SBR ,PBR, Polyesters etc.

Suggested Text Books:

1. Mall. I.D., Petroleum Refining Technology", CBC Publishers.
2. Ram Prasad, Petroleum Refining Technology, Khanna Publishers, Delhi (2000)
3. P. Wiseman, Petrochemicals, John Wiley & Sons, 1986.

Suggested Reference Books:

1. W.L. Nelson, Petroleum Refinery Engineering, McGraw Hill, New York, 1961.
2. S. Matar, Chemistry of Petrochemical Processes, 2nd Ed., Gulf Publishing Company, 2000.
3. J. H. Gary and G. E. Handwork, Petroleum refining technology and economics, 4th Ed., Dekker, 2001.

TCH 463 PRINCIPLES OF POLYMER ENGINEERING

Assessment:

L	T	P	C
3	0	0	3

Sessional: 50 marks

End Semester: 50 marks

Course Objectives

To provide a broad and fundamental knowledge of the polymers and their chemical, physical and mechanical behavior. Emphasis is on the processing techniques like moulding and extrusion.

Course Outcomes:

Students completing the course will be able to

CO1	Connect properties of polymeric materials to their structures and explain how different material parameters and external factors affect the mechanical properties	Remember, Understand
CO2	Decide which test methods are suitable for measurement of mechanical properties	Apply, Analyze, Evaluate
CO3	Correlate structure-processing-properties relationships for polymers, blends and composites	Understand, Apply, Analyze
CO4	Select a suitable processing and manufacturing technique for a given polymer	Understand, Apply
CO5	Identify methods for rheological measurements and analysis of the rheological data using models for non-Newtonian fluids	Understand, Apply, Analyze

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	2	1	1	1	1	1	2	1	1	1	1	2	1	1	1
CO2	2	3	1	2	3	2	1	3	1	1	1	2	1	3	1
CO3	1	1	2	3	3	2	2	3	2	3	2	3	3	2	2
CO4	1	1	2	2	1	2	1	1	2	1	2	3	1	2	1
CO5	3	3	1	2	2	2	1	1	3	3	3	3	3	3	1
Avg	1.8	1.8	1.4	2	2	1.8	1.4	1.8	1.8	1.8	1.8	2.6	1.8	2.2	1.2

Module 1 (6 hours)

Addition polymers, Condensation polymers, Copolymers, Cross-linked polymers, Molecular symmetry and the tendency to form crystals, Distribution of relative molecular mass, Structure of the crystal, Crystal shape, Crystallinity, Crystallization and melting, the glass transition temperature, Molecular conformation in the amorphous polymer, the freely jointed chain, the Gaussian chain, Molecular orientation.

Module 2 (6 hours)

Structure of an ideal rubber, Entropy elasticity, elasticity of a network, Stress-strain relationship, Engineering rubbers, The nature of viscoelasticity, Creep, Stress relaxation, Dynamic properties, Theory of linear viscoelasticity, Polymer selection: stiffness.

Module 3 (6 hours)

Yielding, Crazing, Linear elastic fracture mechanics, Elastic-plastic fracture mechanics, Brittle fracture of polymer, rubber toughening, Reinforced plastics, Forming of reinforced plastics, the mechanics of fiber reinforcement, Reinforced rubbers.

Module 4 (6 hours)

The flow properties of polymer melts, Cooling and solidification, Extrusion, Injection moulding, Compression and transfer moulding.

Module 5 (6 hours)

Materials selection, designing for manufacture, Designing for stiffness, Designing for strength, Case Histories.

Suggested Text Books

1 N. G. McCrum, C. P. Buckley and C. B. Bucknall, Principles of Polymer Engineering, 2^{nd} Edition, Oxford University Press, (1997).

TCH 465 BIO-SYSTEM PROCESS

L	T	P	C
3	0	0	3

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objectives

This course will introduce students to key concepts of microbiology and biochemistry that underpin their application in biochemical engineering. Main objective of this course is to make students understand the basic structure and function of microbial cells, key aspects of biochemistry including macromolecules, enzymes and key metabolic pathways and processes. To introduce enzyme kinetics and immobilization techniques, models for microbial growth, design of bioreactors, downstream processing and product recovery in bioprocesses.

Course Outcome

On completion of this course, students will be able to

CO1	Describe and identify the main groups of microorganisms	Remember, Analyze
CO2	Compare the different structures and growth modes of diverse microorganisms	Understand, Apply
CO3	Describe key biochemical and cellular components and biochemical pathways	Remember
CO4	Explain how microorganisms and biochemical processes can be applied in engineered systems and processes	Understand, Apply
CO5	Select a proper bioreactor and decide suitable operating conditions for aerobic and anaerobic systems	Understand, Apply, Analyze

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	2	1	2		2					2		3			
CO2	2	1			2					2		3			
CO3	2	2	1							2		3			
CO4	3	2	3	2	2	2	2			2	2	2	2	2	2
CO5	3	3	3	2	2	2	2			2	2	2	2	2	2
Avg	2.4	1.8	2.25	2	2	2	2			2	2	2.6	2	2	2

Module 1 (6 hours)

Introduction - principles of microbiology, structure of cells, microbes, bacteria, fungi, algae, chemicals of life - lipids, sugars and polysaccharides, amino acids, proteins, nucleotides, RNA and DNA, hierarchy of cellular organization, Principles of genetic Engineering, Recombinant DNA technology, mutation.

Module 2 (6 hours)

The kinetics of enzyme catalyzed reactions - the enzyme substrate complex and enzyme action, simple enzyme kinetics with one and two substrates, determination of elementary step rate constants. Isolation and utilization of Enzymes -production of crude enzyme extracts, enzyme purification, applications of hydrolytic enzymes, other enzyme applications, Enzyme production intercellular and extra cellular enzymes. Immobilized Enzymes: effects of intra and inter-phase mass transfer on enzyme kinetics.

Module 3 (6 hours)

Metabolic pathways and energetic of the cell, concept of energy coupling, Photosynthesis, Carbon metabolism, EMP pathway, TCA cycle and electron transport chain, aerobic and anaerobic metabolic pathways, transport across cell membranes, Synthesis and regulation of bio-molecules.

Module 4 (6 hours)

Typical growth characteristics of microbial cells, Microbial Growth: Continuum and Stochastic Models, Factors affecting growth, Batch and Continuous cell growth , nutrient media, enrichment culture, culture production and preservation, Immobilization technology – Techniques of immobilization, Characteristics and applications, Reactors for immobilized enzyme systems.

Module 5 (6 hours)

Introduction to bio-reactors, types, continuously stirred aerated tank bio-reactors, Determination of volumetric mass transfer rate of oxygen from air bubbles and effect of mechanical mixing and aeration on oxygen transfer rate, heat transfer and power consumption, Fermentation: methods and applications; downstream processing and product recovery in bio processes design, analysis and stability of bio-reactors.

Suggested Text Books

1. Biochemical Engineering Fundamentals by J. E. Bailey & D. F. Ollis, McGraw Hill Book Company, 1986.
2. Bioprocess Engineering (Basic Concepts) by M. L. Shuler & F. Kargi, Prentice Hall of India, 2003.

TCH 467 MANAGEMENT OF R&D

L	T	P	C
3	0	0	3

Assessment:

Sessional: 50 marks

End Semester: 50marks

Course Objective:

Objective of this course is to introduce students with various aspects of management of R&D planning, organizing, staffing, scheduling, controlling, budgeting, selection of R&D projects, intellectual properties and ethics in R&D.

Course Outcomes:

Students completing the course will be able to

CO 1	Understand the nuances of research and development	Understand, Analyze
CO 2	Learn about management of R&D planning, organizing, staffing, scheduling	Understand, Analyze, Apply
CO 3	Understand the Methodologies for evaluating the effectiveness of R&D.	Understand, Remember, Evaluate, Apply
CO 4	Learn the role of Intellectual Property Rights and decide the strategies for R&D.	Remember, Apply
CO 5	Manage Human Resource in R&D	Analyze, Apply

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	2	2	2	2	2	2	2	2			2		2	2	2
CO2	2	2	2	2	2	2	2	2			2		2	2	2
CO3	2	2	2	2	2	2	2	2			2		2	2	2
CO4	2	2	2	2	2	2	2	2			2		2	2	2
CO5	2	2	2	2	2	2	2	2			2		2	2	2
Avg	2	2	2	2	2	2	2	2			2		2	2	2

Module 1 (6 hours)

The meaning of 'Research' and 'Development' -How Research differs from Development Role of research, The Structural Components of an R&D Organization.

Module 2 (6 hours)

Management of R&D planning, organizing, staffing, scheduling, controlling, budgeting, Selection of R&D projects.

Module 3 (6 hours)

Methodologies for evaluating the effectiveness of R&D, Research Productivity. Protection of Intellectual Property Rights. Evolving flexible organisation.

Module 4 (6 hours)

Issues relating to managing scientists and technologists as individual, in teams, and in large organisations. Human Resource Management in R&D and Innovation, training, motivation, communication, group dynamics.

Module 5 (6 hours)

Information management for innovation and R&D- strategies, sources, channels, and flows. Standardisation and Quality management.

Suggested Text Books

1. Strategic Management of Technology and Innovation by Burgelman and Maidique, Taylor & Francis (1988).
2. Research and Development Management by Alan Glasser, Prentice-Hall (1982).
3. Research and Development Management in the chemical and Pharmaceutical industry by Peter Bamfield, John Wiley & Sons (2006).

ELECTIVE III (TCH 452-458)

TCH 452 OPTIMIZATION: THEORY AND PRACTICES

Assessment:

L	T	P	C
3	1	0	4

Sessional: 50 marks

End Semester: 50 marks

Course Objectives

The primary goal of this course is to provide an overview of state-of-the-art optimization algorithms, the theoretical principles that underpin them, and to provide students with the modeling skills necessary to describe and formulate optimization problems and their use for solving several types of practically relevant optimization problems arising in process systems engineering.

Course Outcomes:

Students completing the course will be able to

CO1	Identify different types of optimization problems	Understand, Apply
CO2	Explain different optimization techniques	Apply, Evaluate
CO3	Solve various multivariable optimization problems	Analyze, Evaluate
CO4	Solve problems by using Linear Programming	Apply, Evaluate
CO5	Solve optimization problems of staged and discrete processes, understand the concept of specialized & Non-traditional Algorithms	Understand, Apply, Evaluate

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	3	2	3	3				2		1	2	2	3	2
CO2	3	2	3	3	3				3	1			3	3	1
CO3	3	3	3	3	3				3	1			3	3	2
CO4	2	3	2	3	3				2				2	3	2
CO5	3	3	2	3	3				2			2	3	2	2
Avg	2.8	2.8	2.4	3	3				2.4	1	1	2	2.6	2.8	1.8

Module 1 (8 hours)

Introduction to process optimization; formulation of various process optimization problems and their classification. Basic concepts of optimization-convex and concave functions, necessary and sufficient conditions for stationary points.

Module 2 (8 hours)

Optimization of one dimensional functions, unconstrained multivariable optimization- direct search methods. Bracketing methods: Exhaustive search method, Bounding phase method Region elimination methods: Interval halving method, Fibonacci search method, Golden section search method. Point-Estimation method: Successive quadratic estimation method. Indirect first order and second order method. Gradient-based methods: Newton-Raphson method, Bisection method, Secant method, Cubic search method. Root-finding using optimization techniques.

Module 3 (8 hours)

Multivariable Optimization Algorithms: Optimality criteria, Unidirectional search, direct search methods: Evolutionary optimization method, simplex search method, Powell's conjugate direction method. Gradient-based methods: Cauchy's (steepest descent) method, Newton's method. Constrained Optimization Algorithms: Kuhn-Tucker conditions, Transformation methods: Penalty function method, method of multipliers, Direct search for constraint minimization: Variable elimination method, complex search method.

Module 4 (8 hours)

Linear Programming: Graphical solution, Primal Simplex method, Artificial starting solution, Dual Simplex method, Primal-Dual relationship, Duality, Sensitivity analysis. Revised Simplex method.

Module 5 (8 hours)

Transportation problem, Optimization of staged and discrete processes. Dynamic programming, Introduction to Specialized & Non-traditional Algorithms.

Suggested Text Books

1 T.F. Edgar and D.M. Himmelblau, "Optimization of Chemical Processes", Mc Graw Hill, International editions, chemical engineering series, 1989.

2 G.S. Beveridge and R.S. Schechter, "Optimization theory and practice", Mc Graw Hill, Newyork, 1970.

Suggested Reference Books

1 Hamdy A. Taha, " Operation Research", Pearson, 2008

TCH 454 ADVANCED PROCESS CONTROL

Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
3	1	0	4

Course Objectives:

To make the students understand the basic concepts of advanced process control schemes, solve controller tuning problems, design various types of controllers used in chemical process industries.

Course Outcomes:

Students completing the course will be able to

CO1	Design of feedback control systems using frequency response techniques	Understand, Apply
CO2	Solve problems of controller tuning using online trial and error method, Ziegler-Nichol's, Cohen and Coon methods	Understand, Apply
CO3	Design of Advanced Control Schemes involving large dead time or inverse response in feedback control systems	Analyse, Evaluate
CO4	Design of controllers for interacting loops	Apply, Understand, Evaluate
CO5	Decoupling and design of non-interacting control loops such as those found in distillation, heat exchangers etc.	Understand, Apply, Evaluate

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	3	3	3	2	1			2		2		3	2	2
CO2	3	3	3	3	2	1			2			1	3	3	2
CO3	2	3	3	3	1	1			1				3	3	1
CO4	3	3	3	2	2				1		1	1	3	3	2
CO5	3	3	3	3					2		1		3	3	3
Avg	2.8	3	3	2.8	1.75	1			1.6		1.3	1	3	2.8	2

Module 1 (8 hours)

Feedback Control Schemes: Concept of feedback control. Dynamics and analysis of feedback-controlled processes. Stability analysis. Design of Feedback Controller, Frequency response analysis and its applications. Design of Feedback Control Systems using Frequency Response Techniques.

Module 2 (8 hours)

Controller Tuning: Controller tuning, Tuning rules, Online trial and error method, Ziegler-Nichol's method, auto tuning by forced cycling, process reaction curve (PRC), Ziegler-Nichol's formulae based on PRC, Cohen and Coon formulae based on PRC, Integral error criterion.

Module 3 (8 hours)

Advanced Control Schemes: Feedback control of systems with large dead time or inverse response, Control systems with multiple loops, Feedforward and ratio control. Adaptive and inferential control systems.

Module 4 (8 hours)

Multivariable process control: Design of controllers for interactions, Loop interaction, Decoupling of interacting loops.

Module 5 (8 hours)

Multi loop multivariable control: Process and control loop interaction., Cascade control, Ratio control, Singular Value Decomposition (SVD), Relative Gain Array (RGA), I/O pairing., Sensitivity to model uncertainty; failure sensitivity, Decoupling and design of non-interacting control loops. Example - Design of controller and control structure for common industrial processes such distillation, heat exchangers etc. Batch Process: Introduction to advanced control strategies, use of microprocessors in process control.

Suggested Text Books

1 Coughnowr and Koppel, "Process Systems Analysis and Control", McGraw-Hill, NewYork, 1986.

2 George Stephanopolous, "Chemical Process Control", Prentice-Hall of India Pvt-Ltd., New Delhi, 1990.

3 P. K. Sarkar, “Process Dynamics and Control”, Prentice Hall India, 2014.

Suggested Reference Books

1 D. N. Considine, “Process Instrumentation and Controls Handbook”, Considine, McGraw Hill.

2 Emenule, S. Savas, " Computer Control of Industrial Processes ", McGraw-Hill, London, 1965.

3 Principals and Practice of Automatic Process Control, Carlos A. Smith and Armando B. Corripio, John Willy & Sons, 2nd Ed.

TCH 456 MATHEMATICAL METHODS IN CHEMICAL ENGINEERING

Assessment:

L	T	P	C
3	**1**	**0**	**4**

Sessional: 50 marks

End Semester: 50 marks

Course Objectives

To learn various computational techniques for analyzing and solving chemical engineering problems.

Course Outcomes:

Students completing the course will be able to

CO1	Solve problems of ordinary differential equations	Apply, Evaluate, Create
CO2	Solve problems using power series methods	Apply, Evaluate, Analyze
CO3	Solve problems of Bessel's equations	Understand, Apply, Evaluate
CO4	Solve problems involving matrices and determinants	Understand, Apply, Evaluate, Analyze, Create
CO5	Solve problems of partial differential equations	Understand, Apply, Evaluate

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	3	3	2	3							2	1	3	1
CO2	3	3	2	2	3					1			2	1	1
CO3	3	2	2	2	3					1		1	1	2	1
CO4	3	2	2	3	3					1		1	1	2	2
CO5	3	3	2	3	3					1		1	2	2	2
Avg	3	2.6	2.2	2.4	3					1		1.25	1.4	2	1.4

Module 1 (10 hours)

Ordinary Differential Equations, Separable equations, Equations made separable by change of variables, Homogeneous Equations, Equations with first order and first degree with linear co-efficients, Exact equations, Linear equation of first order, Bernoulli's equation, Other integrating factors, Integration of Exact equations, Equations of first order and higher degree, Clairaut's equation, Singular solutions, Equations with missing terms, General properties of Linear equations, Linear equations with constant coefficients, Determination of the complementary function, exponential functions, Determination of the particular integral, the Euler equation, Simultaneous Linear Differential equations.

Module 2 (6 hours)

Power series method, theory of the power series method, Legendre's equation, Legendre's Polynomials, Frobenius Method.

Module 3 (8 hours)

Bessel's equation, Bessel Functions $J_v(x)$, Bessel Functions $J_v(x)$ for any $v \geq 0$. Gamma Function, Solution $J_v(x)$ of the Bessel Equation, Backbones of Bessel's Theory, $J_v(x)$ with $v = \pm 1/2, \pm 3/2, \pm 5/2$.

Module 4 (8 hours)

Definition of matrix, Some special definitions and operations involving matrices, Determinants, Theorems on determinants, Inverse of a matrix, Orthogonal and unitary matrix. Orthogonal vectors, System of linear equations, Systems on n equations with n unknowns, Cramer's Rule, eigen values and eigen vectors.

Module 5 (8 hours)

Definition of partial differential equations, types of partial differential equations and solution of partial differential equations.

Suggested Text Books

1 Mickley, Reid and Sherwood, "Applied Mathematics in Chemical Engineering", Tata McGraw Hill, New Delhi (1981).

2 E. Kreyszig, "Advanced Engineering Mathematics", 8^{th} edition, John Wiley and Sons (1999).

3 M. R. Spiegel, “Advanced Mathematics for Engineers and Scientists”, Schaum Outline Series, McGraw Hill, (1971).

TCH 458 STATISTICAL DESIGN OF EXPERIMENTS

Assessment:

L	T	P	C
3	**1**	**0**	**4**

Sessional: 50 marks

End Semester: 50 marks

Course Objectives

Main objective of this course is to introduce various standard experimental designs and methods to analyze the data. To analyze and design the parameters of the systems such that the measure of performances are optimized.

Course Outcomes:

Students completing the course will be able to

CO1	Understand the importance of randomization and replication of experimental data set	Understand, Apply,
CO2	Estimate statistical variance and perform analysis of variance, regression analysis, correlation analysis on a given experimental data	Apply, Evaluate
CO3	Design full factorial and two factor complete factorial experiments and analyse the data	Analyze, Evaluate
CO4	Understanding optimization and gradient optimization method	Apply, Evaluate
CO5	Response surface designs and mixture experiments	Apply, Evaluate

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	2	2	2	3	3				1	1	1	1	2	3	1
CO2	3	3	3	2	3				1	1	1	1	2	3	1
CO3	3	2	3	3	3				2	1	1	1	2	2	1
CO4	2	2	3	3	3				2	1	1	1	2	2	2
CO5	2	2	3	2	2				2	1	1	1	3	3	2
Avg	2.4	2.2	2.8	2.6	2.8				1.6	1	1	1	2.2	2.6	1.4

Module 1 (8 hours)

Introduction to statistics for engineers: Simplest discrete and continuous distributions, Statistical inference, Statistical estimation, tests and estimates on statistical variance, Analysis of variance, Regression analysis (Simple linear, multiple, polynomial, nonlinear), Correlation analysis (Correlation in linear regression, correlation in multiple linear regression). Generalized matrix method for regression model.

Module 2 (8 hours)

Introduction to design of experiments, Preliminary examination of subject of research, Screening experiments. Basic experiment-mathematical modeling, Introduction to ANOVA, completely randomized design, randomized completely block design, latin square design

Module 3 (8 hours)

Complete factorial experiment, two factor complete factorial experiment, 2^n factorial experiment, Fractional factorial design, Box Wilson design. Statistical analysis: Determination of experimental error, Significance of the regression coefficients, Lack of fit of regression models.

Module 4 (8 hours)

Experimental optimization of research subject: Problem of optimization, Deterministic and Stochastic optimization problems. Gradient optimization method, efficiency of gradient method, canonical analysis.

Module 5 (8 hours)

Response surface methodology, central composite design. Box Benken design for fitting response surface, Mixture experiments, Steps of Mixture experiments.

Suggested Text Bookss

1 Z.R.Lazic, Design of experiments in chemical engineering: A practical guide, Wiley (2005).

ELECTIVE-IV (TCH 460-466)

TCH 460 ADVANCED SEPARATION PROCESSES

Assessment:

L	T	P	C
3	**1**	**0**	**4**

Sessional: 50 marks

End Semester: 50 marks

Course Objectives

To understand the governing mechanism and driving forces of various advanced separation processes such as azeotropic distillation, extractive distillation, molecular distillation, reactive distillation, absorption with chemical reaction, supercritical fluid extraction, membrane separation and reverse osmosis; and to perform process and design calculations for these processes.

Course Outcome

On completion of this course, students will be able to

CO1	Explain the importance of modern separation techniques in various applications	Understand, Apply,
CO2	Design novel membranes for intended applications	Apply, Evaluate
CO3	Design supercritical fluid extraction processes	Analyse, Evaluate
CO4	Perform preliminary calculations for multicomponent separation systems including azeotropic and extractive cases	Understand, Apply, Evaluate
CO5	Calculate the rate of reactive absorption processes	Understand, Apply, Evaluate

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	2	1	1	2	1		2	2	3	1
CO2	3	3	3	3	3	2	1	1	2	1		2	2	3	2
CO3	3	3	3	3	3	2	1	1	2	1		2	2	3	3
CO4	3	3	3	3	3	2	1	1	2	1		3	3	3	3
CO5	3	3	1	1	1	1	1	1	2	1		1	1	1	1
Avg	3	3	2.6	2.6	2.6	1.8	1	1	2	1		2	2	2.6	2

Module 1 (8 hours)

Multicomponent distillation – Bubble point and dew point calculations, Lewis and Matheson calculation, Method of Thiele and Geddes, Azeotropic distillation, Extractive distillation, Molecular distillation, Reactive distillation.

Module 2 (8 hours)

Absorption with chemical reaction, Enhancement factor, Simultaneous diffusion and chemical reaction near an interface – Film theory, Penetration theory, Surface renewal theory for a first-order irreversible reaction; Effect of reversibility of the chemical reaction on the mass-transfer rate; Computation of reaction effect for a few chemical situations – absorption of CO_2 and H_2S from a gas stream into aqueous solution of KOH etc.

Module 3 (8 hours)

Supercritical fluid extraction: Supercritical fluids, Phase equilibria, Industrial applications. Important supercritical processes: Decaffination of coffee, Extraction of oil from seeds, Residuum oil supercritical extraction (ROSE), Supercritical fluid chromatography, Supercritical fluid reactions etc.

Module 4 (8 hours)

Classification of membrane processes; Liquid permeation membrane processes or dialysis: Series resistance in membrane processes, Dialysis processes, Types of equipment for dialysis. Gas permeation membrane processes: Types of membranes and permeabilities for separation of gases, Types of equipment for gas permeation membrane processes (flat membranes, spiral-wound membranes, hollow-fibre membranes), Types of flow in gas permeation, Complete-mixing model, cross-flow model and countercurrent flow model for gas separation by membranes, Effect of processing variables on gas separation by membranes.

Module 5 (8 hours)

Reverse osmosis membrane processes: Osmotic pressure of solution, flux equation, Types of equipment and Complete mixing model; Effect of operating variables; Concentration polarization; Permeability constants. Ultrafiltration membrane processes: Types of equipment, flux equation, effects of processing variables

Suggested Text Books

1 Geankoplis C. J., Transport Processes and Unit Operations, Prentice-Hall of India Pvt. Ltd., New Delhi (2000).

2 Sherwood T.K., Pigford R.L. and Wilke C.R., Mass Transfer, McGraw-Hill, New York (1975).

Suggested Reference Books

1 Treybal R.E., Mass-Transfer Operations, McGraw-Hill, New York (1980).

TCH 462 CONCEPTUAL DESIGN OF CHEMICAL PROCESSES

Assessment:

L	T	P	C
3	**1**	**0**	**4**

Sessional: 50 marks

End Semester: 50 marks

Course Objective

Objective of this course is to introduce students to the systematic procedure for the conceptual design of chemical processes. The goal of a conceptual design is to find the best process flow sheet and estimate the optimum design conditions. The course addresses an introduction to engineering economics, including a discussion of various measures of profitability, design of a gas absorber, recycle structure and flow sheet, compressor design, design of minimum-energy heat exchanger networks, cost diagram and the quick screening of process alternatives.

Course Outcomes:

Students completing the course will be able to

CO 1	Estimate capital and operating costs, total capital investments, total product costs	Understand, Analyze
CO 2	Understand input-output structure of flow sheet, equilibrium limitations	Understand, Analyze
CO 3	Design heat exchanger networks, minimum heating and cooling requirements, minimum number of exchanges, area estimates	Apply, Analyze, Evaluate
CO 4	Estimate the cost diagram and the quick screening of process alternatives	Analyze, Evaluate
CO 5	Approximate optimum design conditions	Analyze, Evaluate

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	2	3	1										1	2	3
CO2	3	3	3										1	2	3
CO3	3	3	3	2	1								1	2	1
CO4	3	3	3	2	1								2	2	3
CO5	3	3	3	2	1								2	2	2
Avg	2.8	3	2.6	2	1								1.4	2	2.4

MODULE 1 (8 hours):

Creative aspects of Process Design; A hierarchal approach to conceptual design; Engineering Economics –Cost information required, Estimating capital and Operating costs, Total capital investments and Total product costs, Time value of money, Measures of process profitability.

MODULE 2 (8 hours):

Economic Decision Making: Design of a Gas Absorber – Flow sheet, Material and Energy Balances, and stream costs, Rules of thumb. Input-output structure of the flow sheet: Decisions for the Input-Output Structure; Design variables, Overall Material Balances, and Stream Costs.

MODULE 3 (8 hours):

Recycle structure of the flow sheet - Recycle material balances, Reactor heat effects, Equilibrium limitations. Separation system – General structure, Vapor recovery system, Liquid separation system: column sequencing.

MODULE 4 (8 hours):

Heat exchanger networks – minimum heating and cooling requirements, minimum number of exchangers, area estimates, Design of minimum-energy heat exchanger networks.

MODULE 5 (8 hours):

Cost diagram and the quick screening of process alternatives; Preliminary process optimizations – Design variables and Economic Trade-offs, Cost models for process units, A cost model for a simple process.

Suggested Text Book:

1. James M Douglas, Conceptual Design of Chemical Processes, McGraw-Hill, 1988.

TCH 464 ENERGY RESOURCES AND ENERGY CONSERVATION

L	T	P	C
3	1	0	4

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective

Main purpose of this course is to introduce various conventional (coal and petroleum) and non-conventional energy resources (solar, nuclear, wind, tidal, geothermal), ways of harnessing energy from these sources and its distribution and utilization. This course also focuses on various approaches for energy conservation in a chemical industry.

Course Outcomes

Students completing the course will be able to

CO1	Demonstrate understanding of the different types of renewable and non-renewable energy technologies that are currently available and how they are used to provide energy	Understand, Apply
CO2	Identify strengths and limitations associated with different energy technologies	Apply, Evaluate
CO3	Realize that for sustainability of natural resources, our primary global energy resource profile must shift toward renewable resources	Analyse, Evaluate
CO4	Evaluate different energy technologies based on efficiency, impacts and other factors	Apply, Evaluate
CO5	Evaluate different ways to conserve energy in different con- texts and the social and environmental impacts of renewable and non-renewable energy use	Apply, Evaluate

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	3	2	1	1	1	2	3	1	1			1	2	1	2
CO2	2	2	2	2		2	2		1	1	2	1	2	2	2
CO3	2	2	2	1		1	2		1	1	1		2	2	2
CO4	3	2	2	1	1	2	2		2		1		2	2	2
CO5	2	1	2	1	1	1	2	1	1				2	1	2
Avg	2.4	1.8	1.8	1.2	1	1.6	2.2	1	1.2	1	1.33	1	2	1.6	2

Module 1 (8 hours)

Energy scenario, classification of energy sources, need for conserving energy, government initiative for conserving energy (Role of bureau of energy efficiency, energy conservation bill 2001), energy efficiency based on first and second laws of thermodynamics; Thermodynamic analysis of processes.

Module 2 (8 hours)

Coal - coal analysis, coal classification, coal preparation, coal washing and coal blending, coal carbonization, coal gasification, liquid fuel synthesis from coal; Crude petroleum -chemistry, composition, classification; Crude oil distillation, composition, properties and application of liquid fuels - gasoline, kerosene, ATF, diesel, fuel oil; Gaseous fuels: natural gas, water gas, producer gas, L.P.G., bio-gas, coke oven gas, blast furnace gas, LNG, CNG, CBM, gas hydrates.

Module 3 (8 hours)

Nuclear energy: nuclear raw materials, nuclear reactors, electricity generation from nuclear power, nuclear installations in India and their generation capacities; Solar Energy: solar thermal and photovoltaic conversion and utilization methods, Solar cells, their material and mode of operation; Solar thermal energy storage - sensible heat and latent heat storage materials, chemical energy storage; Solar ponds.

Module 4 (8 hours)

Biomass: conversion routes to gaseous and liquid fuels; Biodiesel; Wind energy: basic principles of wind energy conversion, performance of wind mills, electricity generation from wind; Hydroelectric energy - potential and production; Geothermal energy - potential and production; Ocean energy: ocean thermal energy conversion (OTEC), tidal power plants.

Module 5 (8 hours)

Equipment-oriented approaches for energy conservation - fired heater, boiler, evaporators, distillation column, absorption/stripping column, dryer, liquid-liquid extraction column; Waste heat recovery: sources of waste heat, feasibility of waste heat recovery, types of heat recovery equipments, applications; Energy conservation opportunities in chemical process utilities -

steam systems, compressed air systems, insulation; Cogeneration-A plausible approach for energy conservation

Suggested Text Books

1. Brame J.S.S. and King J.G., Edward Arnold "Fuel Solid, Liquid and Gases" Edward Arnold (1967).

2. Sukhatme S.P, "Solar Energy - Principles of Thermal Collection and Storage", 2nd Ed., Tata McGraw- Hill., (1996).

3. Murphy W.R. and Mckay G., Energy Management (BH)

Suggested Reference Books

1. Boyle "Renewable Energy: Power for a sustainable future" 3rd Ed., Oxford (2012).

2. Rao S. & Parulckar B.B. "Energy technology", 3rd Ed., Khanna Publisher (1994).

TCH 466 INDUSTRIAL POLLUTION CONTROL AND WASTE MANAGEMENT

L	T	P	C
3	**1**	**0**	**4**

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective:

To learn the essential principles used in industrial pollution abatement and understand important issues in industrial pollution abatement and pertinent environmental acts and legislations.

Course Outcomes:

Students completing the course will be able to

CO1	Demonstrate comprehensive understanding of various types of pollution from chemical industries and various regulations pertinent to air, solid and water pollution.	Understand, Apply
CO2	Suggest process modifications to reduce pollution and waste from a chemical industry by employing recycle and reuse.	Apply, Evaluate
CO3	Describe gravity settling chamber, cyclones, electrostatic precipitator, fabric filters and absorbers for air pollution control.	Analyze, Evaluate
CO4	Describe anaerobic and aerobic reactors for biological treatment of waste water.	Apply, Evaluate
CO5	Identify ways to dispose, minimize or utilize hazardous solid waste from chemical industries and understand the ethical issues and societal impact of releasing pollutants in environment.	Apply, Evaluate

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	1	1	1	1	2	3	1	1	1	1	2	2	3	2
CO2	3	1	3	2	1	3	3	1	2	1	3	2	2	2	3
CO3	2	2	3	3	2	2	3	1	2	1	2	3	3	3	3
CO4	2	3	3	3	2	1	3	2	1	1	2	3	3	2	2
CO5	1	1	2	2	1	2	3	3	3	1	3	2	2	3	3
Avg	2.2	1.6	2.4	2.2	1.4	2	3	1.6	1.8	1	2.2	2.4	2.4	2.6	2.6

Module 1 (7 hours)

Introduction: Industrial Pollution and types of pollution from chemical process industries, Characterization of emission and effluents, Global consideration of environmental pollution, Environmental legislation - Water Act 1974, Air Act 1981, Environmental Protection Act 1986; Standards for liquid effluents from chemical process industries, air quality, nuclear radiation emission, noise emission.

Module 2 (8 hours)

Pollution Prevention: Process modification, Alternative raw material, Recovery of by product from industrial emission/effluents, Recycle and reuse of waste, Energy recovery and waste utilization, Material and energy balance for pollution minimization, Water minimization, Fugitive emission/effluents and leakages and their control-housekeeping and maintenance.

Module 3 (10 hours)

Air Pollution Control: Air pollutants classification, Equipments for controlling particulate and gaseous pollutants, lapse rate, atmospheric stability, Dispersion models, Plume behavior, Stack design, Design of gravity settling chamber, cyclones, electrostatic precipitator, fabric filters and absorbers, Air pollution control for petroleum refineries and cement plants.

Module 4 (7 hours)

Water Pollution Control: Waste water characteristics, Primary, secondary and tertiary treatments for wastewater, Anaerobic and aerobic treatment biochemical kinetics, Design of trickling filter, activated sludge systems, ponds and lagoons and aeration systems, Water pollution control for petroleum refineries, fertilizer industry, pulp and paper industry.

Module 5 (8 hours)

Solid Waste Management: Characterization of solid wastes-hazardous and non-hazardous wastes, Waste disposal and management laws and guidelines, Non-hazardous industrial wastes-treatment, disposal, utilization and management, Value-extraction from the wastes, Handling, storage and disposal of hazardous wastes, Waste disposal for nuclear power plants.

Suggested Text Books

1. Metcalf & Eddy, “Wastewater Engineering-Treatment and Reuse”, Revised by G. Tchobanoglous, F. L. Burton, and H. D. Stensel, 4th edition. Tata McGraw-Hill, 2003.

2. Mahajan S. P., Pollution control in process industries, Tata McGraw-Hill,1985

3. Peavy H.S., Rowe D.R.s and Tchobanoglous G., Environmental Engineering, McGraw-Hill edition, 1985

Suggested Reference Books

1. Kreith F. and Tchobanoglous G., “Handbook of Solid Waste Management”, 2nd Ed., Mc Graw Hill,2002

2. Pichtel J., “Waste Management Practices: Municipal, Hazardous and Industrial”, 2nd Ed., CRC, 2005

3. Conway R.A. & Ross R.D., “Handbook of Industrial Waste Disposal”, Van-Nostrand Rein-hold, 1980

4. Vallero D., “Fundamentals of Air Pollution”, 4th Ed., Academic Press, 2007

TCH 493 Industrial Report

L	T	P	C
0	**0**	**4**	**2**

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective:

To learn and apply the essential/fundamental principles of Chemical Engineering

Course Outcomes:

Students completing the course will be able to

CO1	Understand and correlate the industrial processes with the technical knowledge gained	Understand, Apply
CO2	Apply the knowledge to develop, manage and implement engineering solutions within the chemical engineering sector	Apply, Evaluate
CO3	Effectively communicate complex technical information through written reports	Apply, Evaluate
CO4	Effectively communicate complex technical information through oral presentations.	Apply, Analyze
CO5	Learn and understand various skills required, along with professional ethics practiced by the industry	Understand, Apply, Evaluate

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2										2	2		
CO2	2	2	2								2	2	2	3	
CO3					3				2	3			2	3	2
CO4									2	3					
CO5					3	1	2	2					2	3	2
Avg	2	2	2		3	1	2	2	2	3	2	2	2	3	2

TCH 495 Seminar

L	T	P	C
0	**0**	**4**	**2**

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective:

To learn and apply the principles of Chemical Engineering through presentation and develop soft skill and communication

Course Outcomes:

Students completing the course will be able to

CO1	To summarize literature survey and infer	Understand, Apply
CO2	To analyse and comprehend the related data	Apply, Analyze,
CO3	To use soft skills for effective presentation	Apply, Analyze,
CO4	Summerize the technical information through written reports	Apply, Evaluate
CO5	Analyse technical and societal impact of the topic	Analyze, Evaluate

PO/CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2									3					
CO2								3	3			3	2	3	
CO3									3	3	2	3			
CO4									3						
CO5						3	2								2
Avg	2					3	2	3	3	3	2	3	2	3	2

TCH 497 Major Project

L	T	P	C
0	**0**	**4**	**8**

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective:

To learn and apply the essential/fundamental principles of Chemical Engineering

Course Outcomes:

Students completing the course will be able to

CO1	Review research literature and identify the complex engineering problems	Understand, Apply
CO2	Apply the technical knowledge to carry out the given task	Apply, Evaluate
CO3	Commit to professional ethics and work effectively as an individual, and as team within the norms of engineering practices	Analyze, Evaluate
CO4	Analyse technical and societal impact of the project	Apply, Evaluate
CO5	Effectively present the project by demonstrating to analyse the results with conclusions	Apply, Evaluate

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	2	3	2									2	3	3	
CO2	2	3	2	2	3						2	2	3	3	
CO3								3	3			3	2	3	
CO4						3	2					2	2		3
CO5										3		2			
Avg	2	3	2	2	3	3	2	3	3	3	2	2.2	2.5	3	3

TCH 498 Major Project

L	T	P	C
0	**0**	**20**	**10**

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective:

To learn and apply the essential/fundamental principles of Chemical Engineering

Course Outcomes:

Students completing the course will be able to

CO1	Review research literature and identify the complex engineering problems	Understand, Apply
CO2	Apply the technical knowledge to carry out the given task	Apply, Evaluate
CO3	Commit to professional ethics and work effectively as an individual, and as team within the norms of engineering practices	Analyze, Evaluate
CO4	Analyse technical and societal impact of the project	Apply, Evaluate
CO5	Effectively present the project by demonstrating to analyse the results with conclusions	Apply, Evaluate

PO/CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	2	3	2									2	3	3	
CO2	2	3	2	2	3						2	2	3	3	
CO3								3	3			3	2	3	
CO4						3	2					2	2		3
CO5										3		2			
Avg	2	3	2	2	3	3	2	3	3	3	2	2.2	2.5	3	3

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