B. TECH. DEGREE PROGRAMME
IN CHEMICAL ENGINEERING

CURRICULUM AND SYLLABI

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 challanges in Chemical Engineering & Allied Field and catering the requirement of present and future stakeholders and society.

OUR MISSION

1. To provide state-of-art technical education to the undergraduate and post graduate students.
2. To create a conducive and supportive environment for the overall growth of our students.
3. To cultivate awareness of social responsibilities in students to serve the society.
4. 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.
5. To impart consultancy services to the Chemical and Allied industries of the local region and state.

For UG

Programme Educational Outcomes (PEOs)

1. Graduates from our department will be proficient in varied areas of Chemical Engineering that are industrially and academically significant such as Petroleum Refining, Process Control, Fertilizer Manufacturing, Molecular Modeling and Simulation and Nanotechnology.
2. Graduates will exhibit entrepreneurship, leadership and high professional skills while still maintaining ethical and moral values.
3. Graduates will continuously strive and align their activities for the betterment of the society.

Programme Specific Outcomes (PSOs)

1. Apply the knowledge and analytical ability to solve Petroleum and Fertilizer industry problems.
2. Analyze and formulate economically viable solutions for waste management systems.
3. Design and development of ecofriendly sustainable chemical engineering processes.

HARCOURT BUTLER TECHNICAL UNIVERSITY KANPUR
SCHOOL OF CHEMICAL TECHNOLOGY
DEPARTMENT OF CHEMICAL ENGINEERING

Semester wise Course Structure

B.Tech. Chemical Engineering

(Applicable from Session 17-18 for new entrants)

Year I, Semester-I

Sl. No.	Course Type	Course Code	Subject	Credit	Sessional Marks				Sem. Final Exam.	Subject Total
					CT	TA	Lab.	Total		
1	BSC	BCY-101	Engineering Chemistry	4 [3-0-2]	15	20	15	50	50	100
2	BSC	BMA-101	Mathematics-I	4 [3-1-0]	30	20	-	50	50	100
3	ESC	EET-101	Electronics & Instrumentation Engineering	3 [3-0-0]	30	20	-	50	50	100
4	ESC	ECS-101	Computer Concepts & Programming	4 [3-0-2]	15	20	15	50	50	100
5	ESC	ECE-101	Engineering Graphics	3 [0-0-6]	30	20	-	50	50	100
6	ESC	EWS-101	Workshop Practice	2 [0-0-4]		20	30	50	50 (Lab Final)	100
7	MC (Non Credit)	ECE-103	Environment and Ecology	0 [2-0-0]	30	20	-	50	50	100
			Total Credits	**20**						

Year I, Semester-II

Sl. No.	Course Type	Course Code	Subject	Credit	Sessional Marks				Sem. Final Exam.	Subject Total
					CT	TA	Lab.	Total		
1	BSC	BMA-102	Mathematics-II	4 [3-1-0]	30	20	-	50	50	100
2	BSC	BPH- 102	Physics	4 [3-0-2]	15	20	15	50	50	100
3	ESC	EEE- 102	Electrical Engineering	4 [3-0-2]	15	20	15	50	50	100
4	ESC	EME- 102	Engineering Mechanics	3 [3-0-0]	30	20	-	50	50	100
5	HSMC	HHS- 104	Professional Communication	3 [2-0-2]	15	20	15	50	50	100
6	HSMC	HHS- 102	English Language and Composition	2 [2-0-0]	30	20	-	50	50	100
			Total Credits	**20**						

B.Tech. Chemical Engineering
(Applicable from Session 18-19)

Year II, Semester-III

Sl. No.	Course Type	Course Code	Subject	Credit	Sessional Marks				Sem. Final Exam.	Subject Total
					CT	TA	Lab.	Total		
1	BSC	BMA 201	Mathematics III	4 [3-1-0]	30	20	-	50	50	100
2	PCC	TCH 201	Material and Energy balance	4 [3-1-0]	30	20	-	50	50	100
3	PCC	TCH 203	Fluid Mechanics	3 [3-0-0]	30	20	-	50	50	100
4	PCC	TCH 205	Particle & Fluid Particle Processing	3 [3-0-0]	30	20	-	50	50	100
5	PCC	TCH 207	Heat Transfer Operation	3 [3-0-0]	30	20	-	50	50	100
6	PCC	TCH 209	Chemical Engg. Lab -I	2 [0-0-6]	-	20	30	50	50	100
7	HSMC	HHS 203	Organisational Behaviour	3 [3-0-0]	30	20	-	50	50	100
8	MC (Non Credit)	ECS 205)	Cyber Security	0[2-0-0]	30	20	-	50	50	100
			Total Credits	**22**						

Year II, Semester-IV

Sl. No.	Course Type	Course Code	Subject	Credit	Sessional Marks				Sem. Final Exam.	Subject Total
					CT	TA	Lab.	Total		
1	BSC	BCY 202	Modern Analytical Techniques	4 [3-0-2]	15	20	15	50	50	100
2	BSC	BMA 206	Computer Oriented Numerical Methods	4 [3-0-3]	15	20	15	50	50	100
3	PCC	TCH-202	Chemical Engineering Thermodynamics-I	3 [3-0-0]	30	20	-	50	50	100
4	PCC	TCH 204	Mass Transfer Operation-I	3 [2-1-0]	30	20	-	50	50	100
5	PCC	TCH 206	Process Utility	3[3-0-0]	30	20	-	50	50	100
6	PCC	TCH 208	Chemical Engg. Lab-II	2 [0-0-6]	-	20	30	50	50	100
7	HSMC	HHS 202	Engineering Economics & Management	4 [3-0-0]	30	20	-	50	50	100
8	(Non Credit)	HHS206	Indian Constitution	0[2-0-0]	30	20	-	50	50	100
			Total Credits	**22**						

B.Tech. Chemical Engineering
(Applicable from Session 19-20)

Year III, Semester-V

Sl. No.	Course Type	Course Code	Subject	Credit	Sessional Marks				Sem. Final Exam.	Subject Total
					CT	TA	Lab.	Total		
1	PCC	TCH 301	Chemical Technology-I	3 [3-0-0]	30	20	-	50	50	100
2	PCC	TCH 303	Chemical Reaction Engineering-I	4 [3-1-0]	30	20	-	50	50	100
3	PCC	TCH 305	Mass Transfer Operation -II	4 [3-1-0]	30	20	-	50	50	100
4	PCC	TCH 307	Process Instrumentation	3 [3-0-0]	30	20	-	50	50	100
5	PCC	TCH 309	Chemical Engineering Thermodynamics-II	4 [3-1-0]	30	20	-	50	50	100
6	PCC	TCH 311	MTO –II Lab	1[0-0-3]	-	20	30	50	50	100
7	HSMC	HHS 341	Entrepreneurship Development	3 [3-0-0]	30	20	-	50	50	100
			Total Credits	**22**						

Year III, Semester-VI

Sl. No.	Course Type	Course Code	Subject	Credit	Sessional Marks				Sem. Final Exam.	Subject Total
					CT	TA	Lab.	Total		
1	PCC	TCH 302	Process Control	3 [2-1-0]	30	20	-	50	50	100
2	PCC	TCH 304	Chemical Reaction Engineering -II	3 [2-1-0]	30	20	-	50	50	100
3	PCC	TCH 306	Computer Aided Equipment Design	3 [2-1-0]	30	20	-	50	50	100
4	PCC	TCH 308	Transport Phenomena	3 [2-1-0]	30	20	-	50	50	100
5	PCC	TCH 310	Chemical Technology-II	2 [2-0-0]	30	20	-	50	50	100
6	PCC	TCH 312	Plant Design and Economics	3 [2-1-0]	30	20	-	50	50	100
7	PCC	TCH 314	Reaction Engg. & Instrumentation Control Lab	2 [0-0-6]	-	20	30	50	50	100
8	BSC	BMA 302	Operation Research	3 [3-0-0]	30	20	-	50	50	100
			Total Credits	**22**						

B.Tech. Chemical Engineering
(Applicable from Session 20-21)

Year IV, Semester-VII

Sl. No.	Course Type	Course Code	Subject	Credit	Sessional Marks				Sem. Final Exam.	Subject Total
					CT	TA	Lab.	Total		
1	PCC	TCH 419	Open Elective - I	3 [3-0-0]	30	20	-	50	50	100
2	PCC	TCH 401	Process Modeling and Simulation	3 [2-1-0]	30	20	-	50	50	100
3	PCC	TCH 405 - 11	Elective-I	3 [3-0-0]	30	20	-	50	50	100
4	PCC	TCH 413 - 17	Elective-II	3 [3-0-0]	30	20	-	50	50	100
5	PCC	TCH 403	Design & Simulation Lab	2 [1-0-3]	-	20	30	50	50	100
6	PCC	TCH 451	Seminar	2 [0-0-4]	-	50	-	50	50	100
7	PCC	TCH 453	Industrial Report	2 [0-0-4]	-	50	-	50	50	100
8	PCC	TCH 455	Educational Tour	Non Credit	-	-	-	-	-	-
9	PCC	TCH 497	Project	4 [0-0-8]	-	50	-	50	50	100
			Total Credits	**22**						

*** For Project, Seminar & Industrial Training; TA 50 marks by Supervisor and Rest 50 by DPGC**

Year IV, Semester-VIII

Sl. No.	Course Type	Course Code	Subject	Credit	Sessional Marks				Sem. Final Exam.	Subject Total
					CT	TA	Lab.	Total		
1	PCC	TCH 402-408	Elective-III	4 [3-1-0]	30	20	-	50	50	100
2	PCC	TCH 410-416	Elective-IV	4 [3-1-0]	30	20	-	50	50	100
3	PCC	TCH 418	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**						

* Viva-Voce will be conducted by External Examiner
* TA 50 marks by supervisor and Rest 50 by External Examiner

LIST OF ELECTIVES

Open Elective-I [3-0-0]

TCH 419	Energy Resources and Utilization

Open Elective-II [3-1-0]

TCH 418	Air Pollution Monitoring and Control

Elective-I [3-0-0]

TCH 405	Nano Technology
TCH 407	Colloids & Interface Science and Engineering
TCH 409	Corrosion Science and Engineering
TCH 411	Chemical Plant Safety and Risk Assessment
TCH 413	Non Conventional Energy

Elective-II [3-0-0]

TCH 415	Petroleum Refining Engineering
TCH 417	Principles of Polymer Engineering
TCH 421	Biochemical Conversion Processes
TCH 423	Petro Chemical Technology
TCH 425	Material Science & Technology

Elective-III [3-1-0]

TCH 402	Optimization : Theory and Practices
TCH 404	Advanced Process Control
TCH 406	Mathematical Methods in Chemical Engineering
TCH 408	Statistical Design of Experiments

Elective-IV [3-1-0]

TCH 410	Advanced Separation Processes
TCH 412	Process Integration
TCH 414	CFD
TCH 416	Industrial Pollution Control and Waste Management
TCH 418	R&D Management

TCH-201 MATERIAL AND ENERGY BALANCE

L	T	P	C
3	1	0	4

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective:

To understand and apply the basics of calculations related to material and energy flow in the processes.

Course Outcome

Students completing the course will be able to

CO 1. Demonstrate comprehensive understanding of material and energy balance equations for open and closed systems.

CO 2. Select appropriate basis and conduct degree of freedom analysis before solving material and energy balance problems.

CO 3.Make elementary flow-sheets and perform material and energy balance calculations without and with chemical reactions, and involving concepts like recycle, bypass and purge.

CO 4. Perform process calculations utilizing psychrometric charts and steam tables.

CO 5. Apply simultaneous material and energy balance calculations for steady state continuous flow systems and unsteady state systems.

Module 1 (9 hours)

Dimensions, system of units and their conversions, Mass and volume relations, Basic stoichiometric principles, limiting and excess reactants, Degree of completion, Conversion, selectivity, yield. Ideal gas law, Dalton's Law, Amagat's Law, Introduction to degrees of freedom analysis.

Module 2 (7 hours)

Vapor pressure of liquids and solids, Vapor pressure plot (Cox chart), Vapor pressures of miscible and immiscible liquids and solutions, Raoult's Law and Henry's Law. Humidity and saturation use of humidity charts for engineering calculations.

Module 3 (8 hours)

Material balance without chemical reactions and its application to unit operations like distillation, absorption etc. Material balance with chemical reaction Recycle, bypass and purging.

Module 4 (8 hours)

Heat capacity of gases, liquids and solutions Heat of fusion and vaporization. Steady state energy balance for systems with and without chemical reactions. Calculations and application of heat of reaction combustion, formation, neutralization and solution. Enthalpy-concentration charts. Orsat analysis Calculation of theoretical and actual flame temperatures

Module 5 (8 hours)

Simultaneous material and energy balance. Introduction to Unsteady state material and energy balance.

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. Himmelblau, D.M., “Basic Principles and Calculations in Chemical Engineering" ,sixth Edition, Prentice Hall Inc., 1996.
3. Felder, R.M. & Rousseau, R.W. "Elementary Principles of Chemical Processes ", 3rd edition. JohnWiley. (1999)
4. Bhatt, B.L., VORA, S.M., “Stoichiomentry ", Tata McGraw-Hill, 1976.

Suggested Reference Books

1. Venkataramani, V., Anantharaman, N., Begum, K. M. Meera Sheriffa, “Process Calculations” , Second Edition, Prentice Hall of India.
2. Sikdar, D. C., “Chemical Process Calculations”, Prentice Hall of India.

TCH-203 FLUID MECHANICS

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

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective:

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.

CO2. Formulate nondimensional equations using Buckingham Pi Theorem to find relation between flow variables..

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.

CO4. Select a pump type and pump size to meet thr specific pumping requirements..

CO5. Compare and select suitable device for flow measurement in open and closed channels and troubleshoot any problems in flow meters.

Module 1 (10 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 (8 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 (7 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 (7 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 (8 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.

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).
4. Jain, A. K., “Fluid Mechanics including Hydraulic Machines”, Khanna Publishers, Delhi (2007).

5. Bansal, R. K., "Fluid Mechanics and Hydraulic Machines", Laxmi Publications (P) Ltd., New Delhi (2005).

Suggested Reference Books

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

TCH-205 PARTICLE AND FLUID PARTICLE PROCESSING

Assessment:

L	T	P	C
3	0	0	3

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

CO 1. Calculate drag force and terminal settling velocity for single particles.

CO 2. Explain the significance and usage of different particulate characterization parameters, and
equipment to estimate them.

CO 3. Describe Size reduction energy requirements, estimate performance of equipment, selection
and sizing of equipment.

CO 4. Select appropriate filter and filter aid for given separation and design a filtration unit for constant pressure and constant flow operation.

CO 5. Design a continuous thickener using results of a batch settling test.

CO 6. Calculate pressure drop in fixed and fluidized beds.

CO 7. Calculate power consumption and mixing time in a given mixing or agitation process.

Module 1 (6 hours)

Particle Technology: Particle shape, particle size, different ways of expression of particle size, shape factor, sphericity, mixed particles size analysis, screens – ideal and actual screens, differential and cumulative size analysis, effectiveness of screen, specific surface of mixture of particles, number of particles in a mixture, standard screens, 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, equipment for size reduction – Blake jaw crusher, gyratory crusher, smooth roll crusher, tooth roll crusher, imp actor, attrition mill, ball mill, critical speed of ball mill, ultra fine grinders and cutters.

Module 3 (8 hours)

Flow of Fluid Past Immersed Bodies: Drag, drag coefficient, Pressure drop in a bed of solids– Kozeny – Carman equation, Burke- Plummer, Ergun equation, fluidization, conditions for fluidization, minimum fluidization velocity, types of fluidization, application 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 (5 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, 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, principles of cake filtration

Module 5 (5 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.

Suggested Text books

1. McCabe and Smith, Unit Operations of Chemical Engineering, TMH
2. W.L.Badger and J.T.Banchero, Introduction to Chemical Engineering, TMH (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-207 HEAT TRANSFER OPERATIONS

L	T	P	C
3	0	0	3

Assessment:

Sessional: 50 marks

End Semester: 50 marks

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.

Course outcomes:

Students completing the course will be able to

CO 1. Explain different modes of heat transfer.

CO 2. Calculate heat transfer for one-dimensional; steady and unsteady state conduction in solids using analytical methods.

CO 3. Evaluate heat-transfer by forced convection for laminar and turbulent flows in internal and external configurations by employing basics of the boundary layer concept and empirical correlations.

CO 4. Calculate heat transfer by free convection using dimensionless Grashoff number.

CO 5. Understand phase-change phenomena and latent heat of vaporization, including free convective, nucleate and film boiling, as well as dropwise and film condensation.

CO 6. Design heat exchangers using the log-mean temperature difference, over-all heat transfer coefficient and the effectiveness-NTU methods.

CO 7. Design single and multiple effect evaporators.

Module 1 (10 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, thermal contact resistance, critical radius of insulation, Extended surfaces: heat transfer from a fin, fin effectiveness and efficiency, Introduction to unsteady state heat conduction.

Module 2 (8 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 and natural convection. Forced Convection: Correlation equations for heat transfer in laminar and turbulent flows in a Circular tube and duct, Reynolds and Colburn analogies between momentum and heat transfer, heat transfer to liquid metals and heat transfer to tubes in cross flow.. Natural Convection: Natural convection from vertical and horizontal surfaces, Grashof and Rayleigh numbers.

Module 3 (6 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 (8 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, film wise condensation on a horizontal tube, effect of non-condensable gases on rate of condensation. 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 (8 hours)

Heat Exchangers: Types of heat exchangers, Principal Components of a Concentric tube & Shell-andTube 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 and shell and tube heat exchangers.

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. 6. "Fundamentals of Heat and Mass Transfer", Incropera F.P. and Dewitt D.P 5th Ed., John Wiley.

TCH 209 CHEMICAL ENGINEERING LAB -I

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

FLUID FLOW LAB

Course Objective :

To provide practical knowledge in verification of principles of fluid flow and mechanical operations. Also to impart knowledge in measuring pressure, discharge and velocity of fluid flow.

Course Outcomes:

Students completing the course will be able to

CO 1**.** Demonstrate solid foundation in fluid flow principles

CO 2. Calculate performance analysis in turbines and pumps

CO 3. Develop experimental skills

CO 4. Work in team and develop interpersonal skills

CO 5. Develop skills for technical writing

Syllabus

1. To determine and experimentally verify the type of flow using Reynolds apparatus
2. To determine and experimentally verify Bernoulli's equation using Bernoulli's apparatus
3. To find the friction losses in a Straight pipe, Pipe fittings and Valves & Bend pipe.
4. To determine and experimentally verify pressure drop in a packed bed by Ergun"s equation.
5. To determine and experimentally verify minimum fluidization velocity in a fluidized bed
6. To determine and experimentally verify discharge coefficient of an orifice meter.
7. To determine and experimentally verify discharge coefficient of a Venturimeter.
8. To determine and experimentally verify discharge coefficient of a Rotameter.
9. To determine and experimentally verify discharge coefficient of a V notch in open channel.

MECHANICAL OPERATION LAB

Course Outcomes:

Students completing the course will be able to

CO 1. Learn how to experimentally verify various theoretical principles

CO 2. Visualize practical implementation of chemical engineering equipment

CO 3. Develop experimental skills

CO 4. Work in team and develop interpersonal skills

CO 5. Develop skills for technical writing

Syllabus

1.To study the principle of a hydro-cyclone and find out the efficiency of separation.

2. To determine the average particle size of a mixture of particles by sieve analysis.

3.To determine and experimentally verify Ritinger‟s constant of Jaw crusher.

4.To determine reduction ratio, maximum feed size and theoretical capacity of crushing rolls.

5.To determine the effect of no. of balls on grinding in a Ball mill and comparison of its critical speed with the operating speed.

6. To find out enrichment of the coal sample using a froth flotation cell.

7. To determine and experimentally verify reduction ratio using Pulverizer.

8.To determine and experimentally verify the efficiency of separation of a cyclone separator.

9.To determine reduction ratio & experimentally verify reduction ratio of a Gyratory Crusher

TCH-202 CHEMICAL ENGINEERING THERMODYNAMICS -1

L	T	P	C
3	0	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 and laws of thermodynamics.

CO 2. Calculate changes in system properties and heat and work exchanged with the surrounding for open/close system using mass, energy and entropy balances.

CO 3. Solve problems involving liquefaction, refrigeration and different power cycles.

CO 4. Evaluate the properties of non ideal gases.

Module 1 (4 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 (4 hours)

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

Module 3 (4 hours)

Phases, phase transitions, PVT behavior; description of materials – Ideal gas law, van der Waals, virial and cubic equations of state; Reduced conditions & corresponding states theories; correlations in description of material properties and behavior

Module 4 (4 hours)

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

Module 5 (4 hours)

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

Suggested Text Books

1. Y Cengel and M Boles, Thermodynamics An Engineering Approach, 8^{th} Edition.
2. "Introduction to Chemical Engineering Thermodynamics" by J.M. Smith and H.C. Van Ness, McGraw Hill International Ltd, 2005.
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

Suggested Reference Books

1. M J Moran, H N Shapiro, D D Boettner and M B Bailey, Principles of Engineering Thermodynamics, 8th Edition, Willey .

TCH 204 MASS TRANSFER OPERATION-I

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

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

CO1. Explain the difference between flash, steam, batch, fractional, azeotropic and extractive distillation

CO2. Calculate the extent of separation achieved for a binary or multicomponent system undergoing flash, steam, batch or fractional distillation.

CO3. Select a suitable solvent for liquid-liquid or solid-liquid extraction.

CO4. 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.

CO5. Calculate extent of adsorption for stagewise and continuous contact adsorption operations.

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, molecular and steam distillations.

Module 2 (8 hours)

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 multicomponent distillation system.

Module 3 (6 hours)

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

Module 4 (5 hours)

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

Module 5 (5 hours)

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

Suggested Text Books

1. Treybal, R.E. “Mass Transfer Operations”, 3rd ed. New York: McGraw-Hill, (1980).
2. Seader, J.D. and Henley, E.J., “Separation Process Principles”, 2nd ed., Wiley India Pvt. Ltd., New Delhi (2013).

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).

TCH 206 CHEMICAL PROCESS UTILITIES

Assessment:

L	T	P	C
3	0	0	3

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. Explain the use of various process utilities and their importance in chemical plants

CO2. Select a water treatment method based on given water quality

CO3. Design a steam generation and distribution system for a chemical plant

CO4. Select a proper insulator and insulation thickness for high, intermediate, low and sub zero temperatures

CO5. Design equipments used for humidification and dehumidification

Module 1 (4 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 (5 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. Heat-transfer fluids: Heat-transfer fluid systems-Liquid-phase, vapour-phase systems

Module 3 (4 hours)

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 (3 hours)

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

Module 5 (4 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).

TCH 208 CHEMICAL ENGINEERING LAB -II

L	T	P	C
0	0	4	2

HEAT TRANSFER OPERATION LAB

Course Objective:

This course is designed to introduce a basic study of the phenomena of heat and mass transfer, to develop methodologies for solving a wide variety of practical engineering problems, and to provide useful information concerning the performance and design of particular systems and processes. A knowledge-based design problem requiring the formulations of solid conduction and fluid convection and the technique of numerical computation progressively elucidated in different chapters will be assigned and studied in detail.

Course Outcomes

CO 1. Account for the consequence of heat transfer in thermal analyses of engineering systems. CO 2. Analyze problems involving steady state heat conduction in simple geometries.

CO 3. Develop solutions for transient heat conduction in simple geometries.

CO 4. Evaluate heat transfer coefficients for natural convection.

CO 5. Develop experimental skills

CO 6. Work in team and develop interpersonal skills

CO 7. Develop skills for technical writing

Syllabus

1. To find out the thermal conductivity of liquids.
2. To find out the thermal conductivity of a metal rod.
3. Find out the Heat Transfer Coefficient during drop wise and film wise condensation.
4. Find out the Heat Transfer Coefficient in a vertical and a horizontal condenser.
5. To find out the emissivity of a surface.
6. To find out the overall thermal conductance and plot the temperature distribution in case of a composite wall.
7. To find out the average heat transfer co-efficient of vertical cylinder in natural convection.
8. To find out the Stefan Boltzman‟s constant and compare with the theoretical value.

9. To find out the relation between insulation thickness and heat loss.
10. To find out the overall heat transfer co-efficient of a double pipe heat exchanger.
11. To find out the overall heat transfer co-efficient of 1-2 shell & tube heat exchanger.
12. Study and operation of a long tube evaporator.

MASS TRANSFER OPERATION LAB

Course Outcomes

Students completing the course will be able to

CO 1. Experimentally verify various theoretical principles

CO 2. Develop confidence in handling these mass transfer equipments in chemical process industries.

CO 3. Develop experimental skills

CO 4. Work in team and develop interpersonal skills

CO 5. Develop skills for technical writing

Syllabus

1. Determination of diffusivity of acetone in air.
2. Determination of mass transfer coefficient in an agitated vessel.
3. Determination of mass transfer coefficient for steady state surface evaporation of water at different temperature.
4. Determination of mass transfer coefficient in a wetted wall column.
5. Determination of T-x-y diagram for a binary batch distillation.
6. Verification of *Rayleigh equation* in a binary batch distillation process.
7. Verification of steam distillation equations.
8. Determination of ternary curve for the system acetic acid-water-carbon tetrachloride.
9. Determination of distribution coefficient of a solute in two immiscible liquids.
10. Solid-Liquid extraction – Soxhlet‟s experiment.
11. Liquid - liquid extraction in packed bed.
12. Determination of adsorption kinetics and isotherm at solid-liquid interface.
13. Determination of the rate of drying in a tray dryer.
14. Estimation of efficiency of the fluidized bed dryer

TCH-301 CHEMICAL TECHNOLOGY - I

L	T	P	C
3	0	0	3

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective:

To study process technologies of various organic and inorganic process industries.

Course outcomes:

Students completing the course will be able to

CO1. Understand the role of chemical process engineer in chemical industry

CO2. Identify different unit operations and unit processes in a given process flow diagram

CO3. Demonstrate thorough understanding of some important process industries (chloro-alkali, fertilizers, soaps and detergents, sugar manufacture, petroleum, paper and fermentation etc)

CO4. Identify and solve engineering problems during manufacturing of the above mentioned products.

Module 1 (7 hours)

Introduction of chemical process industry with reference to Indian resources, industries, trade and export potential, small scale industries and rural development. Preparation of process flow diagrams, Instrumentation diagrams and Process symbols. Introduction to the following industries lying emphasis on process flow sheet, material requirements, process conditions, material of construction and design aspects. Carbohydrates: Introduction – Monosaccharides, Disaccharides and Polysaccharides, Important reactions, Starch and its derivatives, Cellulose, Structural aspects of cellulose, Derivatives of Cellulose - Carboxy Methyl Cellulose and gun cotton.

Module 2 (5 hours)

Sugar, Glucose, Production of sugar from sugar cane, Fermentation products such as Alcohol, Acetic acid, Citric acid and antibiotics. Dyes and Pesticides.

Module 3 (5 hours)

Soap, detergent and Surfactants, Glycerin, Fatty acids, Hydrogenation of edible oils, Pulp and paper, Recovery of chemicals from black liquor.

Module 4 (6 hours)

Synthetic and natural fibers: Nylon, Dacron, Terylyne, Polyester and other new products, Viscose rayon, acetate rayon, natural and synthetic rubber, vulcanization and reclaiming of rubber, SBR, Thermosetting and Thermo Plastics (PVC, Polyethylene, Polyurethane, Teflon)

Module 5 (7 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), Finishing processes, sulphur removal process, lube oil manufacture; Petrochemicals (ethylene, propylene, formaldehyde, methanol, ethylene oxide, ethanolamine, cumene, ethylene glycol, ethyl benzene)

Suggested Text Books

1. Dryden, C. E. “Outlines of Chemical Technology” (Edited and Revised by M.Gopal Rao and Sittig M.) East West Press Pvt. Ltd., New Delhi, 3rd Edition (1997).

Suggested Reference Books

1. Austin G. T., Shreve’s Chemical Process Industries”, 5th ed., McGraw Hill (1984).

TCH-303 CHEMICAL REACTION ENGINEERING -I

L	T	P	C
3	1	0	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. Demonstrate understanding of the basic concepts involved in using reaction rate equations and kinetic constants.

CO 2. Develop rate laws for homogenous reactions.

CO 3. Design ideal reactors for single and complex reactions.

CO 4. Determine optimal reactor configurations and operating policies for systems involving single reaction.

CO 5. Design non isothermal reactors and the heat exchange equipment required.

CO 6. Understand to represent flow in real vessels for scale up using dispersion model and tanks in series models.

CO 7. Analyze reactors involving non-ideal flow based on residence time distribution theory.

Module 1 (8 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, zero, first, second and third order reactions, half life period, irreversible reaction in parallel and series, catalytic reaction, auto catalytic reaction, reversible reactions.

Module 2 (7 Hours)

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

Module 3 (7 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.

Module 4 (10 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, Successive irreversible reactions of different orders, reversible reactions, irreversible series-parallel reactions, the Denbigh reactions and their special cases, 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.

Module 5 (8 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, 2nd Edition, Prentice Hall 2001

TCH-305 MASS TRANSFER OPERATIONS-II

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

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, interphase 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 basic laws of mass transfer.

CO 2. Determine mass transfer rates using Fick's Law and estimate diffusion coefficients for liquids and gases.

CO 3. Analyze the Similarity of mass, heat and momentum transfer – Analogy

CO4. Perform calculations on humidification and dehumidification processes using psychrometric chart

CO5. Design staged and continuous contactors for gas absorption system

CO6. Design constant rate drying systems and crystallizers

Module 1 (10 hours)

Mass Transfer and Diffusion: Steady-state ordinary molecular diffusion: Fick's law of diffusion; Velocities in mass transfer, Equimolar counterdiffusion; unimolecular 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: Vapour-liquid equilibrium and enthalpy for a pure substance, vapour pressure temperature curve, Vapour 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. Seader, J.D. and Henley, E.J., "Separation Process Principles", 2nd ed., Wiley India Pvt. Ltd., New Delhi (2013).

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)

TCH 307 PROCESS INSTRUMENTATION

L	T	P	C
3	0	0	3

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objectives:

To gain the knowledge of different process instruments widely used in chemical industries.

Course outcomes:

CO1. Understand the principles involved in measurements, Attain knowledge on different measurement methods employed in industrial processing and manufacturing.

CO2. Application of different pressure measurement devices in Chemical industries.

CO3. Application of different temperature measurement devices in Chemical industries.

CO4. Application of various level and flow measurement devices in Chemical industries.

Module 1 (6 lectures)

Characteristics of measurement system, classification, performance characteristics, dynamic calibration, errors, statistical error analysis, reliability and related topics.

Module 2 (6 lectures)

Temperature measurement, definitions and standards, techniques and classification-temperature measurement using change in physical properties, electrical type temperature sensors, radiation thermometry.

Module 3 (5 lectures)

Measurement of pressure: Manometers, Elastic pressure transducers, Measurement of Vacuum.

Module 4 (7 lectures)

Flow measurement, head types-area flow meters, mass flow meters, positive displacement type flow meters, electrical type flow meters and solid flow measurement. Level measurement, float types- hydrostatic types, thermal effect types, electrical methods and solid level measurement, density and viscosity measurement.

Module 5 (6 lectures)

Instruments for analysis, spectroscopic analysis by absorption, emission, mass, diffraction and color, gas analysis by thermal conductivity, chromatography, moisture analysis and liquid composition analysis, measurement of PH.

Text Book:

1. Singh, S. K. , Industrial Instrumentation and Control , Prentice Hall of India, 2016.

2. Eckman, D.P., Industrial Instrumentation, Wiley Eastern Ltd., New York, 1990

Additional reference books:

1. Patranabis, Principles of industrial instrumentation, Tata Mcgraw Hill, 2008**.**

2. Jain, R.K., Mechanical and Industrial Measurements, Khanna Publishers, 2005.

3. Tattamangalam R. Padmanabhan, Industrial Instrumentation: Principles and Design, Springer Publishing Company, 2009.

4. Nakra and Chaudhary, " Instumentation Measurement and Analysis", Tata McGraw Hill, 1978.

TCH-309 CHEMICAL ENGINEERING THERMODYNAMICS-II

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

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective:

To introduce the concepts of fugacity, activity coefficient, vapour-liquid equilibrium and reaction equilibrium.

Course outcomes:

Students completing the course will be able to

CO 1. Calcualte thermodynamic properties using residual properties.

CO 2. Evaluate dew point and bubble point for two-components and multi-components in equilibrium..

CO 3. Estimate the thermodynamic properties of substances in gas or liquid state of ideal and real mixture

CO 4. Evaluate equilibrium constant and Gibbs free energy change of a chemical reaction by applying criterion of equilibrium.

CO 5. Analyze the effect of change in temperature, pressure and composition on equilibrium conversions for chemical reactions.

Module 1 (10 hours)

First Law and second law, Thermodynamic properties of fluids: property relations for homogenous phases, Maxwell relations, various equations of enthalpy, entropy and internal energy, Residual properties, two phase systems: Clapeyron equation, Estimation of thermodynamic properties by using graphs and tables.

Module 2 (8 hours)

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

Module 3 (6 hours)

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

Module 4 (8 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 (8 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, McGraw Hill International Ltd, 2005.
2. "Chemical Engineering Thermodynamics" by Y.V.C. Rao, Universities Press (India) Ltd. Hyderabad.
3. "Chemical and Process Thermodynamics", Kyle B.G., 3rd ed., Prentice Hall. 1999

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

TCH 311 CHEMICAL REACTION ENGINEERING & PROCESS CONTROL LAB

L	T	P	C
0	0	4	2

Course Objective:

Chemical Reaction Engineering lab provides students the first-hand experience of verifying various theoretical concepts learnt in theory courses. It also serves as a bridge between theory and practice.

Course Outcomes

Students completing the course will be able to

CO 1. Experimentally verify various theoretical principles

CO 2. Operate various types of reactors used in chemical industries

CO 3. Develop experimental skills

CO 4. Work in team and develop interpersonal skills

CO 5. Develop skills for technical writing

Syllabus

1. Study and operation of a packed bed reactor
2. Study of saponification reaction in a batch reactor
3. Study of esterification reaction in a batch reactor
4. RTD study in a CSTR
5. RTD study in a plug flow reactor
6. Study and operation of a plug flow reactor
7. Study and operation of a CSTR
8. Study and operation of a cascade CSTR
9. Study and operation of a coiled tubular reactor
10. Study and operation of an adiabatic batch reactor

TCH 302 PROCES CONTROL

L	T	P	C
2	1	0	3

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective:

Objective is to introduce the fundamentals of process control with applications using P, PI, and PID controllers. The course will teach the students about mathematical models based on transfer function approach for single loop systems, how to obtain dynamic response of closed loop systems, stability analysis in transient and frequency domains, and controller tuning methods.

Course Outcomes:

Students completing the course will be able to

CO 1. Understand and interpret control diagrams

CO 2. Design and tuning of controllers for specific applications

CO 3. Calculate the dynamic response of closed loop systems

CO 4. Check the stability of systems using Bode and Nyquist stability criterion

Module 1 (6 hours)

Introduction to Process control systems, Use of Laplace & Inverse Laplace Transformation in study of Process Dynamics & Control . Dynamic Modeling of a Process, Dynamic behavior of First order system and First order systems in series.

Module 2 (6 hours)

Second & higher order systems for various kind of inputs, Linearization of nonlinear systems, Transportation & Transfer Lag.

Module 3 (6 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.

Module 4 (6 hours)

Closed loop transfer function, Response of closed loop control system for various type of control actions. Concept of stability, Stability Criterion, Routh test for stability.

Module 5 (6 hours)

Introduction to Frequency Response, Bode Plot, Control system design by Frequency Response, Ziegler Nichols Controller Settings, Advanced control strategies, Controller Tunning.

Suggested Text Books

1. Coughnour and Koppel, " Process Systems Analysis and Control ", McGraw-Hill, New York, 1986.
2. George Stephanopolous, "Chemical Process Control ", Prentice-Hall of India Pvt-Ltd., New Delhi, 1990.

Suggested Reference Books

3. P. K. Sarkar, “ Process Dynamics and Control”, Prentice Hall India, 2014
4. D. N. Considine, “Process Instrumentation and Controls Handbook”, McGraw Hill.

TCH 304 CHEMICAL REACTION ENGINEERING-II

L	T	P	C
3	0	0	3

Assessment:

Sessional: 50 marks

End Semester: 50 marks

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

CO 1. Develop rate laws for fluid-fluid and fluid-solid heterogeneous reactions.

CO 2. Identify regions of mass transfer control and reaction rate control and calculate conversion.

CO 3. Explain methods for catalyst preparation and characterization.

CO 4. Identify mechanisms for catalytic reactions and catalyst poisoning.

CO 5. Design reactors for heterogeneous catalytic reactions.

Module 1 (8 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, Fuid-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 plus 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 (5 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 (5 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 (4 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-306 COMPUTER AIDED EQUIPMENT DESIGN

Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
2	0	2	3

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.

Course outcomes:

Students completing the course will be able to

CO 1. Understand the basics of process equipment design and important parameters of equipment design

CO 2. Design internal pressure vessels and external pressure vessels

CO 3. Design special vessels such as tall vessels, self supporting vessels, and skirt (and other support for vertical vessels).

CO 4. Design liquid and gas storage tanks with and without floating roof

CO 5. Select standard piping, flanges, gaskets and bolts associated with the vessels and storage tanks.

Module 1 (6 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, Visco-elastic deformation, Different types of fracture, Corrosion And Prevention: Direct Corrosion, electro-chemical corrosion, Galvanic cells, High temperature corrosion, Passivity, factor influencing corrosion rate, Control and of corrosion-modification of corrosive environment, Inhibitors, Cathodic protection, protective coatings. Corrosion charts, Metal forming techniques (bending, Rolling, Forming) & Metal joining techniques, welding – such as Butt, Lap, fillet, corner. Inspection and testing of process vessel.

Module 2 (6 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, tori-spherical, elliptical & conical.; Introduction to compensation for opening such as nozzles & manholes etc.

Module 3 (6 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.

Module 4 (6 hours)

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 5 (6 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, Compound vessels, Liquid storage tanks, Mechanical design of centrifuges, Centrifugal pressure, Bowl and spindle motion: critical speed.

Suggested Text Books

1. Brownell L. E. and Young H. E., "Process Equipment Design", John Wiley and Sons.2004
2. Bhattacharya B. C., "Introduction of Chemical Equipment Design", CBS Publisher.2003
3. I.S.:2825-1969, "Code for Unfired Pressure Vessels", Bureau of Indian Standards.1969
4. I.S.:803-1962, "Code of Practice for Design, Fabrication and Erection of Vertical Mild Steel Cylindrical Welded Oil Storage Tanks", Bureau of Indian Standards.1962

Suggested Reference Books

1. Moss D. R., "Pressure Vessel Design Manual", 3rd Ed., Gulf Publishers.2004
2. Annartone D., "Pressure Vessel Design", Springer-Verlag2007
3. M.V.Joshi and V.V.Mahajani, "Process Equipment Design "Macmillan India
4. J.M.Coulson, J.F.Richardson and R.H.Sinnott," Chemical Engineering Volume

TCH 308 TRANSPORT PHENOMENA

L	T	P	C
2	1	0	3

Assessment:

Sessional: 50 marks

End Semester: 50 marks

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, forced and free convection, binary diffusion with or without chemical reaction.

Course Outcomes:

Students completing the course will be able to

CO 1. Perform basic vector and tensor analysis

CO 2. Solve transport problems using shell balances

CO 3. Formulate and solve one-dimensional transport problems by using the conservation equations

CO 4. Formulate simple multi-dimensional transport problems

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 annular, creeping flow along a solid sphere.

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)

Unsteady viscous flow, flow near a wall suddenly set in motion Boundary layer theory.

Module 4 (6 hours)

Shell energy balances, temperature profiles, average temperature, energy fluxes at surfaces, Equations of change (non-isothermal), equation of continuity, equation of motion for forced and free convection, equation of energy (non-isothermal).

Module 5 (6 hours)

Definitions of concentrations, velocities & mass fluxes, Fick's law of diffusion, Temperature & pressure dependence of mass diffusivity, Maxwell's law of diffusion. shell mass balance, boundary conditions, diffusion through a stagnant gas film. Diffusion with heterogeneous chemical reaction, Diffusion with homogeneous chemical reaction, Diffusion in to a falling liquid film.

Suggested Text books

1. Bird, R. B., Stewart, W. E. and Lightfoot, E. N., "Transport Phenomena", 2nd edition John Wiley (1960).
2. Bannet, C. O. and Myers J. E., "Momentum Heat and Mass Transfer" Tata McGraw Hill, (1973).

Suggested Reference Books

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

TCH 310 CHEMICAL TECHNOLOGY – II

L	T	P	C
2	0	0	2

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective:

To study process technologies of various organic and inorganic process 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

CO2. Demonstrate thorough understanding of some important process industries (chloro-alkali, fertilizers, urea, sulfur and phosphorous industry, industrial gases, electrothermal industries and cement industry)

CO 3. Make selection regarding raw material requirements, process conditions, construction material and design aspects for the above mentioned industries.

CO4. Identify and solve engineering problems during manufacturing of the above mentioned products.

CO 5. Analyze the potential of chemical process industries with respect to trade and export potential and rural development.

Module 1 (6 hours)

Introduction of chemical process industry with reference to Indian resources, industries, trade and export potential, small scale industries and rural development. Preparation of process flow diagrams, Instrumentation diagrams and Process symbols. ; Introduction to the following industries lying emphasis on process flow sheet, material requirements, process conditions, material of construction and design aspects. Common salt, Caustic soda and Chlorine, Soda Ash, Hydrochloric acid.

Module 2 (6 hours)

Sulfur and sulfuric acid, Oleum, Phosphorus, Phosphoric acid and super phosphates.

Module 3 (6 hours)

Ammonia, Nitric acid, Urea and other nitrogen fertilisers, Mixed fertilisers (NPK, KAP, DAP, Nitrophosphate), Bio fertilizers.

Module 4 (6 hours)

Oxygen, Nitrogen, Hydrogen, Carbon dioxide, Inert gases, Synthesis gases

Module 5 (6 hours)

Electrothermal industries, Aluminum, Magnesium, Lithium, Titanium etc., Electro-chemical sources of energy and storage, Fuel cells, Cement.

Suggested Text Books

1. Dryden, C. E. “Outlines of Chemical Technology” (Edited and Revised by M.Gopal Rao and Sittig M.) East West Press Pvt. Ltd., New Delhi, 3rd Edition (1997).
2. Austin G. T., Shreve’s Chemical Process Industries”, 5th ed., McGraw Hill (1984).

Suggested Reference Books

1. Faith, W. L., Keyes, D. B. and Clark, R. L., “Industrial Chemicals” John Wiley.(1975).
2. Kirk and Othmer, "Encyclopaedia of Chemical Technology" Wiley (2004).

TCH 312 PROCESS DESIGN AND ECONOMICS

L	T	P	C
2	1	0	3

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objectives

The objective of this course is to acquire basic understanding of design parameter, complete knowledge of design procedures for commonly used process equipment in Heat transfer, Mass transfer and other operation., To gain the of knowledge plant economics including capital investment, cash flows, depreciation and profitability.

Course Outcomes:

Students completing the course will be able to

CO 1. Analyse, synthesise and design processes for manufacturing products commercially

CO 2. Integrate and apply techniques and knowledge acquired in other courses such as thermodynamics, heat and mass transfer, fluid mechanics, instrumentation and control to design heat exchangers, condensers, reboilers, jacketed vessels, plate and packed columns for distillation and absorption/stripping.

CO 3. Recognise economic, construction, safety, operability and other design constraints.

CO 4. Estimate fixed and working capitals and operating costs for process plants

CO 5. Evaluate the profitability of process industry projects using different methods of profitability analysis such as ROI, NPV and DCFR.

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 :O'Connell's correlation , Van Winkle's correlation , AIChE method , Entrainment , Approximate column sizing , Plate contactors , Selection of plate type , Plate construction , Plate hydraulic design, Plate-design procedure: Plate areas ,Diameter , Liquid-flow arrangement ,Entrainment ,Weep point , Weir liquid crest , Weir dimensions , Perforated area , Hole size , Hole pitch ,Hydraulic gradient ,Liquid throw , Plate pressure drop , Downcomer design [back-up]. 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. Towler G. and Sinnott R. K., "Chemical Engineering Design", Butterworth-Heinemann.2008
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. Hewitt G. F., Shires G. L. and Bott T. R., "Process Heat Transfer", CRC Press.1994
5. Serth R.W., "Process Heat Transfer: Principles and Applications", Academic Press.2007.
6. 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. Coker A. K., "Ludwig's Applied Process Design for Chemical and Petrochemical Plants", Vol. 1, 4th Ed., Gulf Publishers.2007
2. Ludwig E. E., "Applied Process Design for Chemical and Petrochemical Plants", Vol. 2, 3rd Ed., Gulf Publishers.1997

TCH 314 INSTRUMENTATION & CONTROL LAB (Murged)

L	T	P	C
0	0	2	1

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective:

Objective of the course is to introduce the basics of instrumentation and process control through a hands-on practical experience. Principles of operation of different measuring devices for temperature, level, pressure, flow, pH, humidity, density, and viscosity will be introduced to impart knowledge of transmitters, transducers, converters, control valves, digital and analog components.

Course Outcome

Students completing the course will be able to

CO 1. Verify the various theoretical principles

CO 2. Operate instrumentation and automation systems in modern chemical plant operation.

CO 3. Develop experimental skills

CO 4. Work in team and develop interpersonal skills

CO 5. Develop skills for technical writing

Syllabus

1. Transient response to single tank system with storage & Flow to (a) step change (b) impulse change in put.
2. Transient response of non interacting system in series.
3. Transient response of interacting system in series.
4. Study the operation of ON-OFF electronic temperature controller & determination of its performance to control the temperature of a system having capacity to store thermal energy.
5. Transient response of a CSTR System to step change.
6. Study the dynamics of parallel & counter flow shell & tube heat exchanger.
7. Controlling of Parallel Flow & counter flow STHE using digital PI controller to have desired output.
8. Dynamics characteristics of mercury & water manometers.
9. Study of control value characteristics.
10. Study the performance of cascade control system & to maintain desired level in a tank, with flow.

TCH 419 (OPEN ELECTIVE) ENERGY RESOURCES AND UTILIZATION

L	T	P	C
3	0	0	3

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective

To understand and analyze the present and future energy demand of world and 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

CO 1. Understand the energy demand and resources to fulfil the demand.

CO 2. Effectively utilize available renewable and non renewable energy resources.

CO 3. Explain modern energy conversion techniques.

CO 4. Evaluate different energy technologies based on efficiency, impacts and other factors.

CO 5. Evaluate different ways to conserve energy in different contexts.

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 Energy: Biogas plants and their operation, Biomass and its conversion routes to gaseous and liquid fuels. Wind energy, its potential and generation by wind mills.

Module 2 (6 hours)

Fuel cell ,Solar Energy : Photo thermal and photovoltaic conversion and utilization methods , solar water heating , cooking , drying and its use for other industrial processes ,solar cells their material and mode of operation . direct and indirect methods solar energystorage , sensible heat and latent heat storage materials Solar ponds .Bio energy, biogas plants and their operation ,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, 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, CBM.

Module 5 (6 hours)

Petroleum crude , Types of crude ,emergence of petroleum products as energy, GaseousFuels: Natural gas, Water gas, producer gas, L.P.G., bio- gas, coke oven gas, blast furnace gas, LNG ,CNG,Gas hydrates ,GTL Technology (gas to liquid), Biodisel.

Suggested Text Books

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

Suggested Reference Books

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

TCH 401 PROCESS MODELLING AND SIMULATION

Assessment:

L	T	P	C
2	1	0	3

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

CO 1. Model deterministic systems and differentiate between nonlinear and linear models.

CO 2. Numerically simulate linear and non linear ordinary differential equations for deterministic systems

CO 3. Estimate and validate a model based upon input and output data.

CO 4. Create a model prediction based upon new input and validate the output data

CO 5. Develop steady state models for flash vessels, equilibrium staged processes, distillation columns, absorbers, strippers, CSTR, heat exchangers and packed bed reactors.

CO 6. Demonstrate the knowledge of various simulation packages and available numerical software libraries.

Module 1 (6 hours)

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; Numerical Methods: Iterative convergence methods, Numerical integration of ODE- IVP and ODE-BVP.

Module 2 (6 hours)

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

Module 3 (6 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 (6 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 (6 hours)

Simulation and their approaches, Modular, Sequential, Simultaneous and Equation solving approach, Simulation softwares 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”, Mc Graw Hill.
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”, PHI,(2011)
2. C.D. Holland, “Fundamentals of Modelling Separation Processes”, Prentice Hall, (1975)
3. Hussain Asghar, “Chemical Process Simulation”, Wiley Eastern Ltd., New Delhi, (1986)

TCH 403 COMPUTER APPLICATION AND DESIGN LAB

L	T	P	C
0	0	4	2

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective

To introduce students to use of software packages such as ASPEN, MATLAB, FLUENT for simulation, and also analysing flowsheets

Course Outcomes

CO 1. Solve chemical engineering problems using advanced programming softwares

CO 2. Use simulation softwares like ASPEN and FLUENT

CO 3 Analyse the techno-economic feasibility of chemical manufacturing facility

CO 4. Develop experimental skills

CO 5. Work in team and develop interpersonal skills

CO 6. Develop skills for technical writing

Contents :

1. Solve a non-linear algebraic equation using Newton-Raphson's method.
2. Calculate pressure drop in pipe.
3. Calculate minimum fluidization velocity.
4. Calculate terminal velocity.
5. Solve a system of non-linear equations,
6. Calculate the molar volume of saturated liquid water and saturated water vapour using van der

1. Waals, Redlich-Kwong and Peng-Robinson cubic equation of state.
2. Solve system of simultaneous ordinary differential equations.
3. Solve for outlet temperatures of series of stirred tanks with coil heater.
4. Solve for non-isothermal PFR.
5. Solve for concentration profiles of A, B and C in the series reaction A→B→C.

ELECTIVE I (TCH 405-411)

TCH 405 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

CO 1. Describe the basic science behind the novel properties of materials at the nanometer scale.

CO 2. Demonstrate a comprehensive understanding of the state of the art nanofabrication methods.

CO 3. Compare and select suitable techniques for characterization of a given nanomaterial.

CO 4. Explain how nanotechnology can be put to use in varied areas of science and engineering.

CO 5. Evaluate the impact of nanotechnology on society and environment.

CO 6. Evaluate current constraints such as regulatory, ethical, political, social and economical; when putting nanotechnology to use.

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 buckyballs, fullerenes, metallofullerenes, solid C60, bucky onions, nanotubes, nanowires, nanocones, Carbon nanostructures.

Module 2 (6 hours)

Methods of Synthesis of Nanomaterials: Bottom-up (building from molecular level) and top-down (breakdown of 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.

Module 3 (6 hours)

Top down approach vs Bottom up approach, Optical Microscopy, Electron Microscopy, Secondary electron scattering, back scattering, Scanning Probe Microscopes, Focussed 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, Photocatalysis Nanostructured materials, Self-assembly and Catalysis.

Module 5 (6 hours)

Nanobiotechnology : Drug Delivery, Nanoclay, Nanocomposites, Surface coatings, Self cleaning Materials, Hydrophobic Nanoparticles, Biological nanomaterials, Nanoelectronics, Nanomachines & nanodevices, Nanohydrogel, Photocatalytic reactors, Nanoclay 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

Suggested Reference Books

1. Bhusan B., Springer Handbook of Nanotechnology

TCH 407 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

CO 1: Explain the concepts of surface and interfacial energies and tensions and how they can be measured.

CO 2: Identify the nature of various interparticle forces between colloidal systems and how they can be calculated.

CO 3: Evaluate when stable emulsions will be formed using DLVO and DLVO like theories.

CO 4: Select suitable surfactants for specific applications in nanofluidics and advanced and functional materials.

CO 5: Identify the ways in which wettability of surfaces can be manipulated for preparing superhydrophobic surfaces.

Module 1 (6 hours)

Effects of confinement and finite size, concepts of surface and interfacial energies and tensions, Apolar (aan 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, Vander-waals, electrostatic double layer, acid-base interactios 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, functionsl coatings, structural colours, nano-adhesives, nano-composites.

Suggested Text Books

1. Principles of Colloid and Surface Chemistry, Paul C. Hiemenz, Marcel DEker, 2^{nd} edition and ionwards, 1986.
2. Physical Chemistry of Surfaces, Arthur W. Adamson, 5^{th} 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. Intermolucular 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 409 CORROSION SCIENCE AND ENGINEERING

L	T	P	C
3	0	0	3

Assessment:

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

CO 1. Explain the industrial applications and economic benefits of corrosion control

CO 2. Evaluate if corrosion can occur under specific operating conditions in a given equipment or construction.

CO 3. Determine the probable corrosion type, estimate the corrosion rate and propose the most reasonable protection method as regards safety, price and environmental considerations.

CO 4. Select proper material, design and operating conditions to reduce the likelihood of corrosion in a given equipment.

CO 5. Perform troubleshooting and corrosion monitoring

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 Fe-H2O 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, inter granular, 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, corrosions monitoring methods, chemical and electrochemical removal of corrosion products.

Suggested Text Books

1. S.N. Banerjee, An Introduction to Corrosion and Corrosion Inhibition, Oxonian Press Ltd., New Delhi.
2. LL Shrier Corrosion Vol. I & II George NownonsLtd., Southhampton Street London Endn. II
3. M.G. Fontana & N.D. Greene, Corrosion Engineering, McGraw Hill, New York (3/e)
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, Dhanpat Rai & Sons, New Delhi

TCH 411 CHEMICAL PLANT SAFETY AND RISK ASSESMENT

Assessment:

L	T	P	C
3	0	0	3

Sessional: 50 marks

End Semester: 50 marks

Course Objectives

This course will give an overview of the safety regulations and practices, plant hazards and their control, risk assessment and management principles and techniques and accident analysis.

Course Outcomes:

Students completing the course will be able to

CO 1. Identify and distinguish typical sources of risk and hazard in a process plant.

CO 2. Assess the severity of the consequences of incidents

CO 3. Undertake a Hazard and Operability Study (HAZOP)

CO 4. Explain the legal framework controlling process plant safety in the country

CO 5. Demonstrate how the root cause of incidents can be investigated and analysed and the various human and technical aspects of such causes.

Module 1 (8 hours)

Concepts and definition, safety culture, storage of dangerous materials, Plant layout Safety systems, Occupational Safety and Health Administration (OSHA) incidence rate, Fatal accident rate (FAR), The accident Process: Initiation, Propagation, and Termination, Toxicology: Ingestion, Inhalation, Injection, Dermal Absorption, Dose versus response curves, Relative toxicity, Threshold Limit Values.

Module 2 (6 hours)

Industrial Hygiene: Government regulations, Identification, Industrial hygiene and safety aspects related to toxicity, noise, pressure, temperature, vibrations, radiation etc. Evaluation: Evaluating Exposures to volatile toxicants by monitoring, Estimating worker exposures to toxic vapors, Evaluating workers Exposures to dusts, noise.

Module 3 (6 hours)

Technology and process selection, Scale of disaster, Fire triangle, Distinction between fires and explosion, Definitions of Ignition, Auto-ignition temperature, fire point, flammability limits, Mechanical explosion, Deflagration and detonation, Confined explosion, Unconfined explosion, Vapors cloud explosions, Boiling liquid expanding vapor explosion (BLEVE), Dust explosion, shock wave, Flammability characteristics of liquids and vapors, Minimum oxygen concentration (MOC) and Inerting.

Module 4 (6 hours)

Control of toxic chemicals, Storage and handling of flammable and toxic chemical, Runway reactions, Relief system risk and hazards management, Design to prevent Fires and Explosions: Inerting, Static Electricity, Explosion proof equipment and Instrument, Ventilation, sprinkler systems and Miscellaneous Design for preventing Fires and Explosion.

Module 5 (6 hours)

Hazards Identification: Process hazards checklists, Hazard Surveys, Hazard and Operability Studies (HAZOP), Safety reviews. Risk Assessment: Review of probability Theory, Interaction between process units, Revealed and unrevealed failure, probability of coincidence, Fault trees and Event trees, Hazard models and risk data. Tackling disasters, plan for emergency. Risk management routines, Emergency shutdown systems, Role of computers in safety, Prevention of hazard human element, Technology and process selection.

Suggested Text Books

1. Daniel A. Crowl and Joseph F. Louvar, Chemical Process Safety: Fundamentals with applications, Prentice Hall, Inc, 1990.
2. F. P. Lee’s, Loss prevention in the process Industries, Volume 1 and 2 Butterworth, 1983.
3. Hoboken, N. J., Guidelines for Chemical Process Quantitative Risk Analysis, Wiley-Interscience, 2000.
4. R. W. King and J. Magid, Industrial Hazards and Safety Handbook, Butterworth, 1982.

Suggested Reference Books

1. G. L. Wells, Safety in Process Plant Design, John Wiley and Sons Inc., 1980.
2. Fawcett, H.H. and W.S. Wood, Safety and Accident Prevention in Chemical Operations, 2nd Edition, Wiley-Interscience, New York, 1982.

ELECTIVE-II (TCH 413-419)

TCH 413 FUEL AND COMBUSTION TECHNOLOGY (removed)

L	T	P	C
3	0	0	3

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objectives

To learn about types of fuels and their characteristics, and combustion systems with emphasis on engineering applications

Course Outcomes:

Students completing the course will be able to

CO 1. Critically evaluate the properties of different conventional fuels and compare and evaluate properties such as energy density, polluting effect, cost and availability

CO 2. Demonstrate a comprehensive understanding of complex combustion features: combustion modes, equilibrium products of combustion, economy-emission compromises, laminar and turbulent flames.

CO 3. Calculate adiabatic flame temperatures and calorific value of fuels

CO 4. Suggest ways to improve the efficiency of combustion burners.

Module 1 (6 hours)

History of Fuels-Solid fuels, liquid fuels and gaseous fuels; Production, present scenario and consumption pattern of fuels; Fundamental definitions, properties and various measurements-Definitions and properties of solid fuels, Definitions and properties of liquid and gaseous fuels, Various measurement techniques

Module 2 (6 hours)

Coal classification, composition and basis; Coal mining; Coal preparation and washing; Combustion of coal and coke making-Action of heat on different coal samples, Different types of coal combustion techniques, Coal tar distillation; Coal liquefaction-Direct liquefaction, Indirect liquefaction; Coal gasification

Module 3 (6 hours)

Exploration of crude petroleum; Evaluation of crude; Distillation-Atmospheric distillation, Vacuum distillation; Secondary processing-Cracking-Thermal cracking, Visbreaking, Coking, Catalytic cracking, Reforming of naphtha, Hydrotreatment, dewaxing, deasphalting, Refinery equipments

Module 4 (6 hours)

Natural gas and LPG, Producer gas, Water gas, Hydrogen, Acetylene, Other fuel gases

Module 5 (6hours)

Fundamentals of thermochemistry; Combustion air calculation, Calculation of calorific value of fuels; Adiabatic flame temperature calculation; Mechanism and kinetics of combustion; Flame properties; Combustion burners; Combustion furnaces; Internal combustion engines

Suggested Text Books

1. S. Sarkar, Fuels and combustion, 2nd ed., Orient Longman Ltd., (1990).

Suggested Reference Books

TCH 415 PETROLEUM REFINING ENGINEERING

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

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objectives

Petroleum sector plays the most vital role for keeping the wheels of economic development rolling and the Chemical engineers mainly run the petroleum industry. 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 all the above mentioned 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

CO 2. Demonstrate comprehensive understanding of design and operation of petro refineries and petrochemical complexes

CO 3. Identify and suggest safe practices in operations of refineries and petrochemical complexes

CO 4. Identify challenges, energy security issues and environmental issues

CO 5. Perform techno-economic analysis & trouble shooting

Module 1 (6 hours)

Petroleum Exploration Production and Refining of Crude oils, Crude oils: Characteristics and constituents of crude oils, Classification of crude oils.

Module 2 (6 hours)

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, thermal stability of jet fuels, gum content, Total Sulphur, Acidity and Alkalinity,, Copper Strip Corrosion Test, Silver – Strip Corrosion Test for ATF, Ash, Carbon Residue (Conradson method, Ramsbottom method) Colour, Density and Specific gravity, Refractive index of hydrocarbon liquids, water separation index (modified) (WSIM), ductility.

Module 3 (8 hours)

Petroleum Products: Composition, Properties & Specification of LPG, Naphthas, motor spirit, Kerosine, Aviation Turbine Fuels, Diesel Fuels, Fuel Oils, Petroleum Hydrocarbon Solvents, Lubricating oils (automotive engine oils, industrial lubricating oils electrical insulating oils, Jute Batching oils, white oils, steam turbine oils, metal working oils, etc.) Petroleum Waxes Bitumens, Petroleum coke. **Crude Oil Distillation**: Desalting of crude oils, Atmospheric distillation of crude oil, Vacuum distillation ofatmospheric residue.Thermal Conversion Process: Thermal Cracking Reactions, Thermal Cracking, Visbreaking, (Conventional Visbreaking and Soaker Visbreaking) Coking (Delayed Coking, Fluid Coking, Flexicoking), Calcination of Green Coke.

Module 4 (6 hours)

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

Finishing Process: Hydrogen sulphide removal processes; Sulphur conversion processes; Sweetening processes (Caustic treatment, Solutizer process; Doctor treating process; Copper chloride sweetening,; Hypochlorite sweetening ;Air and inhibitor treating process; Merox processes;Sulphuric acid treatment; Clay treatment); Solvent extraction processes (Edeleanu process, Udex process, Sulfolane process), Hydrotreating processes.

Module 5 (6 hours)

Lube Oil Manufacturing Process: Evaluation of crude oils for lube oil base stocks, Vacuum distillation, Solvent deasphalting Solvent extraction of lube oil fractions (Furfural, NMP and Phenol), Solvent dewaxing, Hydrofinshing, Manufacture of petroleum waxes (Wax sweating, Solvent deoiling)

Manufacture of Bitumens: Selection of crude oil, Methods of manufacture of bitumens, (Distillation, Solvent precipitation, Air blowing).

Suggested Text Books

1. Nelson, W.L., Petroleum Refining Engineering, McGraw Hill
2. Mall. I.D., Petroleum Refining Technology", CBC Publishers.

Suggested Reference Books

1. Mall I. D., Petrochemical Process Technology", CBC Publishers.

2. Ram Prasad, Petroleum Refining Technology, Khanna Publishers, Delhi (2000)

.3. Ludwig vol 1,2 & 3

3. Gary & Hamdwark

TCH 417 PRINCIPLES OF POLYMER ENGINEERING

L	T	P	C
3	0	0	3

Assessment:

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

CO 1. Connect properties of polymeric materials to their structures and explain how different material parameters and external factors affect the mechanical properties.

CO 2. Decide which test methods are suitable for measurement of mechanical properties

CO 3. Correlate structure-processing-properties relationships for polymers, blends and composites

CO 4. Select a suitable processing and manufacturing technique for a given polymer.

CO 5. Indentify methods for rheological measurements and analysis of the rheological data usind models for non-Newtonian fluids.

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 jointe 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 viscoelasticty, 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 fibre 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 419 BIOCHEMICAL CONVERSION PROCESSES

Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
3	0	0	3

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

CO 1. Describe and identify the main groups of microorganisms.

CO 2. Compare the different structures and growth modes of diverse microorganisms.

CO 3. Describe key biochemical and cellular components and biochemical pathways

CO 4. Explain how microorganisms and biochemical processes can be applied in engineered systems and processes.

CO 5. Select a proper bioreactor and decide suitable operating conditions for aerobic and anaerobic systems.

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 biomolecules.

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 Immobilisation Technology–Techniques of immobilisation, Characteristics and applications, Reactors for immobilized enzyme systems.

Module 5 (6 hours)

Introduction to bio reactors, types, Continuously Stirred aerated tank bioreactors, 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 Bioreactors.

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.

Suggested Reference Books

1. Biochemical Engineering by H. W. Blanch & D. S. Clark, Marcel Dekker, Inc., 1997.

ELECTIVE-III (TCH 402-408)

TCH 402 OPTIMIZATION: THEORY AND PRACTICES

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

Assessment:

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 modelling 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

CO 1. Identify different types of optimization problems

CO 2. Explain different optimization techniques

CO 3. Solve various multivariable optimization problems

CO 4. Solve problems by using Linear Programming

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 404 ADVANCED PROCESS CONTROL

L	T	P	C
3	1	0	4

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objectives

Course Outcomes:

Students completing the course will be able to

CO 1. Understand about the most common chemical reactor models. The subject of steady state multiplicity in stirred tank reactors and develops uniqueness criteria for various cases that may be of interest for design.

CO 2. Understand the terms such as steady and stable. The students should apply the knowledge to explore the implications of the stability concept in dealing with finite disturbances of practical magnitude.

CO 3. Analyze from ordinary differential equation models to partial differential equation models.

CO 4. Apply the knowledge of steady state multiplicity, local stability, and regional stability are treated for distributed systems.

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 criterions.

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 406 MATHEMATICAL METHODS IN CHEMICAL ENGINEERING

Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
3	1	0	4

Course Objectives

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

Course Outcomes:

Students completing the course will be able to

CO 1. Solve problems of algebraic equations.

CO 2. Solve problems of differential equations and simultaneous equation.

CO 3. Solve problems of partial differential equations.

CO 4. Analyze Stirred-tank Reactor System, Distillation in a Plate Column and Unsteady-state Operation by solving differential equations.

CO 5. Assess reasonableness of solutions, and select appropriate levels of solution sophistication

Module 1 (8 hours)

Ordinary Differential Equations, Separable equations, Equations made separable by change of variables, Homogeneous Equations, Equations with first order and first degree with linear coefficients, 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 (8 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)

Analysis of Stagewise Processes by the Calculus of Finite Differences, Countercurrent Liquid-Liquid Extraction, Solution of Difference Equations, Stirred-tank Reactor System, Distillation in a Plate Column, Unsteady-state Operation, Starting a Stirred-tank Reactor, Rate at which a Plate Absorber Approaches Steady State.

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).

Suggested Reference Books

1. M. R. Spiegel, "Advanced Mathematics for Engineers and Scientists", Schaum Outline Series, McGraw Hill, (1971).

TCH 408 STATISTICAL DESIGN OF EXPERIMENTS

Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
3	1	0	4

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

CO 1. Understand the importance of randomization and replication of experimental data set.

CO 2. Estimate statistical variance and perform analysis of variance, regression analysis, correlation analysis on a given experimental data

CO 3. Design full factorial and fractional factorial experiments and analyse the data

CO 4. Develop nested designs, block designs and response surface designs

CO 5. Recognize what design was followed and perform the appropriate analysis given the description of how a set of data was collected.

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 or 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, design of orthogonal arrays. Screening design `composition-property', Simplex lattice design,

Suggested Text Books

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

ELECTIVE-IV (TCH 410-416)

TCH 410 ADVANCED SEPARATION PROCESSES

Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
3	1	0	4

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

CO 1. Explain the importance of modern separation techniques in various applications.

CO 2. Design novel membranes for intended applications

CO 3. Design chromatography and dialysis based separation processes.

CO 4. Perform preliminary calculations for multicomponent separation systems including azeotropic and extractive cases.

CO 5. Calculate the effect of operating variables such as Concentration, polarization, permeability constants on reverse osmosis process

CO 6. Explain how supercritical fluid extraction can be used in various industrial aaplications

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. C.J.Geankoplis, Transport Processes and Unit Operations, Prentice-Hall of India Pvt. Ltd., New Delhi (2000).
2. T.K.Sherwood, R.L.Pigford and C.R.Wilke, Mass Transfer, McGraw-Hill, New York (1975).

Suggested Reference Books

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

TCH 412 PROCESS INTEGRATION

L	T	P	C
3	1	0	4

Assessment:

Sessional: 50 marks

End Semester: 50 marks

Course Objective

To learn process integration with regard to energy efficiency, waste minimization and an efficient use of raw materials.

Course Outcomes:

Students completing the course will be able to

CO 1. Perform pinch analysis employing grid diagrams, composite curves, Problem Table algorithm and Grand Composite Curve.

CO 2. Optimize Heat exchanger Networks employing super targeting i.e. energy targeting, area targeting, number of units targeting, shell targeting and cost targeting.

CO 3. Design for multiple utilities pinches

CO 4. Modify processes for minimization of waste water and raw water.

CO 5. Demonstrate understanding of heat and power integration

Module 1 (8 hours)

Introduction to Process Intensification and Process Integration (PI). Areas of application and techniques available for PI, onion diagram. Pinch Technology-an overview: Introduction, Basic concepts, How it is different from energy auditing, Roles of thermodynamic laws, problems addressed by Pinch Technology Basic Elements of Pinch Technology: Grid Diagram, Composite curve, Problem Table Algorithm, Grand Composite Curve.

Module 2 (8 hours)

Key steps of Pinch Technology: Concept of ΔT min , Data Extraction, Targeting, Designing, Optimization-Super targeting Targeting of Heat Exchanger Network: Energy Targeting, Area Targeting, Number of units targeting, Shell Targeting and Cost targeting.

Module 3 (8 hours)

Designing of HEN: Pinch Design Methods, Heuristic rules, stream splitting, and design of maximum energy recovery (MER). Use of multiple utilities and concept of utility pinches, Design for multiple utilities pinches, Concept of threshold problems and design strategy. Network evolution and evaluation-identification of loops and paths, loop breaking and path relaxation. Design tools to achieve targets, Driving force plot, remaining problem analysis, diverse pinch concepts, MCp ratio heuristics.

Module 4 (8 hours)

Targeting and designing of HENs with different ΔTmin values, Variation of cost of utility, fixed cost, TAC, number of shells and total area with ΔTmin Capital-Energy trade-offs. Process modifications-Plus/Minus principles, Heat Engines and appropriate placement of heat engines relative to pinch. Heat pumps, appropriate placement of heat pumps relative to pinch Steam Rankin Cycle design, Gas turbine cycle design, Integration of Steam and Gas turbine with process

Module 5 (8 hours)

Refrigeration systems, Stand alone and integrated evaporators. Heat integrations and proper placement of Reactors for batch Processes as well as continuous processes. Retrofit of distillation systems. Various case studies.

Suggested Text Books

1. Shenoy U. V.; "Heat Exchanger Network Synthesis", Gulf Publishing company.
2. Smith R.; "Chemical Process Design", McGraw-Hill .

Suggested Reference Books

1. Linnhoff B., Townsend D. W., Boland D, Hewitt G. F., Thomas B. E. A., Guy A. R., and Marsland R. H.; "A User Guide on Process Integration for the Efficient Uses of Energy", Inst. Of Chemical Engineers .
2. Douglas

TCH 414 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.

CO 2. Identify strengths and limitations associated with different energy technologies.

CO 3. Realize that for sustainability of natural resources, our primary global energy resource profile must shift toward renewable resources.

CO 4. Evaluate different energy technologies based on efficiency, impacts and other factors.

CO 5. Evaluate different ways to conserve energy in different contexts.

CO 6. Evaluate the social and environmental impacts of renewable and non renewable energy Use

CO 7. Understand their personal and professional role in energy conservation.

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, Generation of Nuclear power, Nuclear installations in India and their generation capacity; 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, Electric generation for wind; Hydroelectric energy-Potential and production; Geothermal energy-Potential and production; Ocean Energy conversion Technologies, 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” Oxford.
2. Rao S. & Parulckar B.B. ”Energy technology” Khanna Publisher

TCH 416: 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 pollutions.

CO2: Suggest process modifications in order to reduce pollution and waste from a chemical industry by employing recycle and reuse.

CO3: Design gravity settling chamber, cyclones, electrostatic precipitator, fabric filters and absorbers for air pollution control..

CO4: Perform design calculations for anaerobic and aerobic reactors for biological treatment of waste waterCO5: Identify the best way to dispose, minimize or utilize haradous solid waste from chemical industries.

CO 6: Understand the ethical issues and societal impact of releasing pollutants in environment.

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. 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", CRC, 2005
3. Conway R.A. & Ross R.D., "Handbook of Industrial Waste Disposal", Van-Nostrand Reinhold, 1980
4. Vallero D., "Fundamentals of Air Pollution", 4th Ed., Academic Press, 2007
5.

OPEN ELECTIVE - II

TCH 418 **AIR POLLUTION MONITORING AND CONTROL(removed)**

Environment safety and Hazard Analysis

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

Assessment:

Sessionals: 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

CO 1. Demostrate comrehensive understanding of different types of air pollutants and various standards and acts regarding the air pollutants of global concern.

CO 2. Select proper sampling and analysis method for a specific gaseous or particulate air pollutant.

CO 3. Analyze plume behavior and come up with a suitable stack design based on meteorological aspects of air pollution.

CO 4. Select and design the most economical industrial dust collector for control of particulate emission at the source itself.

CO 5. Design absorption columns for control of gaseous pollutants.

CO 6. Design three way catalytic converters for pollution control from automobiles.

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: Green house 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, 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 (10 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, PrenticeHall of India pvt Ltd, N.Delhi.1996
2. Y.B.G. Verma, H. Brauer," Air Pollution Control Equipments", Springer, Berlin, 1981