

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

**Semester wise Course Structure**

**B.Tech. (Chemical Technology Branches)  
(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		TCH 201	Material and Energy balance	3 [2-1-0]	30	20	-	50	50	100
2		TCH 211	Fluid Mechanics & Mechanical Operation	5 [3-1-3]	15	10	25	50	50	100
3										
4										
5										
			<b>Total Credits</b>	<b>22</b>						

- Necessary softwares (Aspen Plus, Hysis, etc) to be provided by technology branch

**Year II, Semester-IV**

Sl. No.	Course Type	Course Code	Subject	Credit	Sessional Marks				Sem. Final Exam.	Subject Total
					CT	TA	Lab.	Total		
1		TCH 212	Heat Transfer Operations	3 [3-0-0]	30	20	-	50	50	100
2		TCH 214	Chemical Engineering Thermodynamics	3 [3-0-0]	15	20	-	50	50	100
3										
4										
5										
			<b>Total Credits</b>	<b>22</b>						

**B.Tech. (Chemical Technology Branches)**  
**(Applicable from Session 18-19 for new entrants)**

**Year III, Semester-V**

Sl. No.	Course Type	Course Code	Subject	Credit	Sessional Marks				Sem. Final Exam.	Subject Total
					CT	TA	Lab.	Total		
1		TCH 315	Mass Transfer Operation	4 [3-1-0]	30	20	-	50	50	100
2		TCH 317	Chemical Reaction Engineering	4 [3-1-0]	30	20	-	50	50	100
3										
4										
5										
			<b>Total Credits</b>	<b>22</b>						

**Year III, Semester-VI**

Sl. No.	Course Type	Course Code	Subject	Credit	Sessional Marks				Sem. Final Exam.	Subject Total
					CT	TA	Lab.	Total		
1		TCH 316	Instrumentation & Process Control	5 [3-1-3]	30	20	-	50	50	100
2						20	30	50	50	100
3										
4										
5										
			<b>Total Credits</b>	<b>22</b>						

**B.Tech. (Chemical Technology Branches)**  
**(Applicable from Session 18-19 for new entrants)**

**Year IV, Semester-VII**

Sl. No.	Course Type	Course Code	Subject	Credit	Sessional Marks					Sem. Final Exam.	Subject Total
					CT	AT	TA	Lab.	Total		
1											
2											
3											
4											
5											
			<b>Total Credits</b>	<b>22</b>							

**Year IV, Semester-VIII**

Sl. No.	Course Type	Course Code	Subject	Credit	Sessional Marks				Sem. Final Exam.	Subject Total
					CT	TA	Lab.	Total		
1		TCH 420	Transport Phenomena	3 [2-1-0]	30	20	-	50	50	100
2		TCH 422	Process Modeling and Simulation	3 [2-1-0]	30	20	-	50	50	100
3										
4										
5										
			<b>Total Credits</b>	<b>22</b>						

## TCH-201 MATERIAL AND ENERGY BALANCE

### Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
2	1	0	3

### 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.

CO4. 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., "Stoichiometry ", 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-211 FLUID MECHANICS & MECHANICAL OPERATIONS

### Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
3	1	0	4

### Course Objective:

To understand basic concept of fluid flow and its application to chemical process industries including pipe flow, fluid machinery and agitation & mixing.

### Course outcomes:

CO 1. Understand the need of fluid mechanics for chemical engineers.

CO 2. Understand the basic terms and their concepts of fluid flow

CO 3. Apply the knowledge to develop a dimensional number for the fluid flow.

CO 4. Understand the fundamentals in characterization and classification of solids.

CO 5. Understand the sieving performances using different sieve size.

CO 6. Calculate the crushing efficiency of different size reduction equipment using crushing laws

### Module I (8 hours)

Introduction to process fluid mechanics; Fundamental concepts: Definition of a fluid; Continuum hypothesis; Velocity field; Stress field; Newtonian and non-Newtonian fluids, Fluid statics: pressure variation in a static fluid, hydrostatic forces on submerged surfaces, buoyancy, Manometers. Dimensional analysis and similitude: Buckingham Pi theorem and applications

### Module II (8 hours)

Macroscopic Balances: derivation of integral balances for mass, energy and momentum; Derivation of engineering Bernoulli equation with losses, Application of macroscopic balances: Losses in expansion, Force on a reducing bend, Diameter of a free jet; Jet ejector. Flow measurement: Orifice meter, venturi meter, Pitot tube, and Rotameter.

### Module III (8 hours)

Differential balances of fluid flow: derivation of continuity and momentum (Navier-Stokes) equations for a Newtonian fluid, Boundary layer theory, Pipe flows and fittings: laminar and turbulent flows; friction factor charts, losses in fittings, Fluid transportation: Valves and Pumps and Compressors.

### Module IV (8 hours)

Flow through packed and fluidized beds: Flow through beds of solids, motion of particles through the fluid, Particle settling, Fluidization, minimum fluidization velocity, Mixing and Agitation- power consumption, mixing times, scale up

### **Module V (8 hours)**

Filtration: Governing equations, constant pressure operation, constant flow operation, cycle time, types of filters. Centrifuges and Cyclones: Gravity settling, centrifugal separation, cyclone separations, separation efficiency, pressure loss,

### **Reference**

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. W.L.Badger and J.T.Banchero, Introduction to Chemical Engineering, TMH (1979)

## TCH-211 FLUID MECHANICS & MECHANICAL OPERATIONS LAB

### Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
0	0	2	1

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 discharge coefficient of an orifice meter.
5. To determine and experimentally verify discharge coefficient of a Venturi meter.
6. To determine and experimentally verify discharge coefficient of a Rotameter.
7. To determine and experimentally verify discharge coefficient of a V notch in open channel.
8. To determine the average particle size of a mixture of particles by sieve analysis.
9. To determine and experimentally verify Rittinger's constant of Jaw crusher.
10. To determine reduction ratio, maximum feed size and theoretical capacity of crushing rolls.
11. To determine the effect of no. of balls on grinding in a Ball mill and comparison of its critical speed with the operating speed.
12. To find out enrichment of the coal sample using a froth flotation cell.



## TCH-212 HEAT TRANSFER

### Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
3	0	0	3

### 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:

CO 1. Understand different modes of heat transfer.

CO 2. Apply the concepts of one-dimensional and multi-dimensional; steady and unsteady state conduction heat transfer, and relevant boundary and initial conditions in problem solving.

CO 3. Apply the knowledge of analytical and graphical (temperature charts) techniques in solving specific transient heat conduction problems, including lumped and one-dimensional systems.

CO 4. Understand the concept of temperature-dependent buoyancy which causes natural free convection, and apply the dimensionless Grashof number used in correlations for free convective heat transfer calculations.

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.

### Module 1 (6 hours)

Introduction of heat transfer and general concepts of heat transfer by conduction, convection and radiation, Conduction: Basic concepts of conduction in solids, liquids, gases, steady state temperature fields and one dimensional conduction without heat generation e. g. through plain walls, cylindrical and spherical surfaces, composite layers, Insulation materials, critical and optimal, insulation thickness, Extended surfaces, fins and their applications, Introduction to unsteady state heat transfer.

## **MODULE 2 (6 hours)**

Convection: Fundamentals of convection, Basic concepts and definitions, natural and forced convection, hydrodynamic and thermal boundary layers, laminar and turbulent heat transfer inside tubes, Dimensional analysis, determination of individual and overall heat transfer coefficients, heat transfer in molten metals.

## **MODULE 3 (6 hours)**

Radiation: Basic laws of heat transfer by radiation, black body and gray body concepts, view factors, Kirchoff's law, solar radiations, combined heat transfer coefficients by convection and radiation.

## **MODULE 4 (6 hours)**

Heat Transfer by phase change: Condensation of pure vapours, film wise and drop wise condensation, heat transfer in boiling liquids, boiling heat transfer coefficients, Evaporation: Elementary principles, types of evaporators, Single and multiple effect evaporators.

## **MODULE 5(6 hours)**

Heat exchangers: Types of heat exchangers, Principal components of a concentric tube & shell-and-tube heat exchangers, baffles, tube and tube distribution, tubes to tube sheet joint, heat exchanger with multiple shell and tube passes, log-mean temperature difference, overall heat transfer coefficient, fouling factors, design of double pipe and shell and tube heat exchangers.

## **BOOKS:**

1. "Heat Transfer principles and applications" Dutta, B. K., PHI
2. "Heat Transfer" Holman J. P, 9th Ed. McGraw Hill.
3. "Process Heat Transfer". Kern D. Q. McGraw Hill Book
4. Heat and Mass Transfer Fundamentals and Applications, Cengel Y. A. and Ghajar A. J., McGraw Hill, 5th edition, 2016.

## TCH-214 CHEMICAL ENGINEERING THERMODYNAMICS

### Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
3	0	0	3

### Course Objective:

To understand the theory and applications of classical thermodynamics, thermodynamic properties, equations of state, methods used to describe and predict phase equilibria.

### Course outcomes:

CO 1. Understand the basic of thermodynamics and the terminology associated with engineering thermodynamics. and

CO 2. Understand the knowledge of contemporary issues related to chemical engineering thermodynamics

CO 3. Understand the knowledge of phase equilibria in two-component and multi-component systems.

CO 4. Analyse the thermodynamic properties of substances in gas or liquid state of ideal and real mixture

CO 5. Understand intermolecular potential and excess property behaviour of multi-component systems

### Module 1 (8 hours)

Basic Concepts & First Law of Thermodynamics: Scope of thermodynamics, System & Surroundings, Properties -Force, Temperature & pressure, Equilibrium, Processes- Reversible & Irreversible, Work, Heat, Energy ,Phase rule, Joule's Experiment, Internal energy, Enthalpy, Heat capacities, Application of first law to closed & open systems. Volumetric properties of pure fluids: PVT behavior of pure substances, Virial equation of state and its application ,ideal gas and cubic equation of state, Generalized correlations for gases and liquids.

### Module 2 (6 hours)

Second Law of Thermodynamics: Heat engine and its efficiency, Heat pump, Refrigerator, COP, Second law of Thermodynamics, Kelvin–Planck statement & Clausius Statement, Carnot's cycle

and Carnot theorems, Clausius inequality, Entropy balance for open systems, ideal work and lost work, Principle of entropy.

**Module 3 (6 hours)**

Residual properties, two phase systems: Clapeyron equation, Estimation of thermodynamic properties by using graphs and tables. Solution thermodynamics Theory: Fundamental property relation, Chemical potential and phase equilibria, Partial properties, Ideal gas mixture model.

**Module 4 (6 hours)** Fugacity and fugacity coefficient for pure species and in solution, Ideal solution model and excess properties. Solution thermodynamics Application: Liquid phase properties from VLE data, Models for the excess Gibbs energy, Property changes of mixing.

**Module 5 (4 hours)** Phase Equilibria: Nature of equilibrium, phase rule, VLE qualitative behavior, Simple Models for VLE, VLE by Modified Raoult's law and VLE from K-value charts.

**Reference**

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
4. "Chemical Engineering Thermodynamics", by Narayanan, K.V., Prentice Hall. 2007

## TCH 315 MASS TRANSFER OPERATION

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 most important separation equipments in the process industry, and provide proper understanding of unit operations.

### Course outcomes:

CO1. Understand the principles of molecular diffusion and basic laws of mass transfer.

CO2. Ability to determine mass transfer rates using Fick's Law

CO3. Estimate diffusion coefficients

CO4. Ability to determine convective mass transfer rates

CO5. Analyze the Similarity of mass, heat and momentum transfer – Analogy

CO6. Understand the humidification processes and use of psychometric chart

### Module I (8 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. Introduction to absorption.

### Module II (8 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 III (8 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 IV (8 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. Introduction to Humidification and drying.

### **Module V (8 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. Introduction to Crystallization theory.

### **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).
3. Sherwood, T. K., Pigford, R. L. and Wilke, C.R. "Mass Transfer" McGraw Hill (1975).
4. Geankoplis, C.J. "Transport Processes and Separation Process Principles", 4th ed., PHI Learning Private Limited, New Delhi (2012).

## TCH-317 CHEMICAL REACTION ENGINEERING

### Assessment:

Sessional: 50 marks

End Semester: 50 marks

L	T	P	C
3	1	0	4

**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.

### Course Outcomes:

CO1. Able to develop an understanding of the basic concepts involved in using reaction rate equations and kinetic constants.

CO2. Perform derivations of rate equations for non-elementary reactions both in homogenous and in heterogeneous reacting systems.

CO3. Able to understand the role of temperature and concentration in the rate equation.

CO4. Perform constant volume batch reactor calculations

CO5. Develop calculations using the integral method and applying differential method of analysis using reactions with different orders

### Module I (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 II (8 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 III (8 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 IV (8 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 V (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.

**Reference Books:**

Levenspiel, O., "Chemical Reaction Engineering", 3rd edition, John Wiley (1998).



## TCH 316 INSTRUMENTATION & PROCESS CONTROL

L	T	P	C
3	1	0	4

### Assessment:

Sessional: 50 marks

End Semester: 50 marks

### Course Objectives:

To gain the knowledge of different process instruments and process control.

### Course outcomes:

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

CO5. Understand the uses of different temperature measurement devices in Chemical industries.

### Module 1 (8 hours)

Introduction to Process control systems, Use of Laplace & Inverse Laplace Transformation in study of Process Dynamics & Control. Characteristics of measurement system, classification of measuring instruments.

### Module 2 (8 hours)

Dynamic Modeling of a Process, Dynamic behavior of First order system, First order systems in series & second & higher order systems for various kind of inputs, Linearization of nonlinear systems, Transportation & Transfer Lag.

### Module 3 (8 hours)

Classification of control systems, Regulator & Servo control, Feed Forward & Feed backward control, Negative & Positive Feed back Control, Modes of control action, Controllers & Final control Elements, Reduction of Block & Signal Flow Diagrams.

**Module 4 (8 hours)**

Principles of measurements and classification of process control instruments, Functional elements of an instrument, Static & Dynamic Characteristics of instruments, Transducers, Error analysis, Measurement of temperature: expansion thermometers, Resistance Thermometers, thermocouples, Thermistors, Pyrometers.

**Module 5 (8 hours)**

Flow measurement: Inferential flow measurements, Quantity flowmeters, Mass flowmeters. Flow measurement, head types-area flow meters, mass flow meters, positive displacement type flow meters, electrical type flow meters and solid flow measurement.

**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.
3. Singh, S. K. , Industrial Instrumentation and Control , Prentice Hall of India, 2016
- 4 . Eckman, D.P., Industrial Instrumentation, Wiley Eastern Ltd., New York, 1990

## TCH 318 INSTRUMENTATION & PROCESS CONTROL

L	T	P	C
0	0	2	1

### Assessment:

Sessional: 50 marks

End Semester: 50 marks

### INSTRUMENTATION AND PROCESS CONTROL LAB

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 420 TRANSPORT PHENOMENA

L	T	P	C
3	0	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 (7 hours)

Introduction to 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 (7 hours)

The equation of continuity, the equation of motion, use of the equations of change to set up steady flow problems and applications.

### Module 3 (4 hours)

Flow near a wall suddenly set in motion, Boundary layer theory and applications.

**Module 4 (6 hours)**

Shell energy balances, temperature profiles, average temperature, energy fluxes at surfaces, Equations of change, equation of motion for forced and free convection and applications.

**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 and applications.

**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: A Unified approach", McGraw-Hill Book,(1988).

## TCH 422 PROCESS MODELING AND SIMULATION

L	T	P	C
3	0	0	3

### Assessment:

Sessional: 50 marks

End Semester: 50 marks

### Course Objectives:

This course explores the basic concepts and steady state equations of simple systems in chemical process industries. It deals with the techniques for derivation of system model equations, data analysis and visualization. The course aims to present the basic idea and concept on process model with detailed analysis and solution of model equations for steady 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.

### **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.

### **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)