### Theory Subject

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<th>Theory Subject</th>
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L: Lectures/Week  
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P: Practical Hours/Week  
C: Number of Credits
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(THIRD AND FOURTH SEMESTERS)
EXAMINATIONS 2010 - 2011
SCHEME OF TEACHING AND EXAMINATION

THIRD AND FOURTH SEMESTERS

Third and fourth semesters will be exclusively devoted to thesis work. The student would be required to present one term paper by the middle of the third semester and one seminar before the submission of M.E. thesis and would carry 100 marks each. These would be presented before the Department Faculty and the students of the Department. The evaluation will be done by a board consisting of:

(i) Chairman or his nominee
(ii) Thesis Supervisor
(iii) A member of the Department Faculty to be nominated by the Chairman of the Department out of a panel of 3 persons to be suggested by the Supervisor.

Allotment of Marks

| (i) First Semester | 1200 |
| (ii) Second Semester | 1300 |
| (iii) Comprehensive Viva | 200 |
| (iv) Term Paper | 100 |
| (v) Seminar | 100 |

**Total Marks** 2900

Thesis work will be based on the research work conducted in the Department on an approved topic under the supervision of a faculty member of the Department or it can be based on the training in an Industrial/R&D organization of repute under joint supervision of one supervisor from the industry and the other from the Department.

Note: No numerical marks are to be assigned to thesis work. It is either “Accepted” or “Rejected”. Quality of work reported in the thesis can be graded in terms of “Very Good”, “Good” or “Average”.
SYLLABUS FOR
M. E. (CHEMICAL ENGINEERING)
FIRST SEMESTER

1.1 MATHEMATICAL METHODS IN CHEMICAL ENGINEERING


Approximate and numerical solutions of PDE’s: Finite difference approximation to derivatives. Numerical solutions of elliptic equations (Laplace and Poisson’s equations), Parabolic equations and Hyperbolic equations.

Integral Functions: Gamma functions, Beta functions, Elliptic integrals and functions and error functions.

Solution methods for linear difference equations, complementary solutions and particular solutions. Nonlinear equations (Riccati equations).

Z-Transforms: Introduction, some standard Z-transforms, linearity property damping rule, some standard results, shifting rules, initial and final value theorems, convolution theorem, evaluation of inverse transforms, applications to difference equations.


(20 Hrs.)

(10 Hrs.)

Books Recommended:


1.2 ADVANCED FLUID MECHANICS

1. Dimensional Analysis: Buckingham, Pi-theorem, Rayleigh method, geometric, kinematic and dynamic similarity, scale up numerical problems on pumps, drag force and agitation. (5 Hrs.)

2. Differential Equations of fluid flow: Continuity equation for one dimensional and three dimensional flows. Derivation of momentum equation for three dimensional flow in Cartesian coordinates. (5 Hrs.)
3. **Flow of non-viscous flows**: Equation of motion (Euler equation) and its integration to obtain Bernoulli equation, velocity potential and irrotational flow. Streamlines and stream functions for two dimensional incompressible flow, two dimensional irrotational flow and flow net. (5 Hrs.)

4. **Laminar flow of viscous fluids**: Effects of viscosity on flow, pressure gradient in steady uniform flow, use of momentum equations in cylindrical coordinates, velocity profiles in isothermal flow in circular tubes and annuli and friction factor relations. Flow in infinite parallel plates and shear stress. Velocity profiles in non-isothermal conditions. (6 Hrs.)

5. **Turbulent flow of viscous fluids**: Prandtl’s mixing length theory, Reynolds equation for incompressible turbulent flow. Reynolds stresses, statistical theory of turbulence, intensity of turbulence, scale of turbulence, measurement of turbulence, hot wire anemometer and its use in turbulence parameters, isotropic and homogeneous turbulence. (6 Hrs.)

6. **Turbulent flow in closed conduits**: Prandtl’s power law of velocity distribution, logarithmic and universal velocity distribution equations for turbulent flow in smooth tubes. Friction factor for rough and smooth tubes, relationship of $u^+$ and $y^+$ to the friction factor and Reynolds number. (6 Hrs.)

7. **Flow of incompressible fluids past immersed bodies**: Von-Karman integral momentum equation, boundary layer on immersed bodies, equation of two dimensional flow in the boundary layer, local and total drag coefficients. Transition from laminar to turbulent flow on the flat plate. (4 Hrs.)

8. **General Topics**: (a) High velocity measurement techniques for fluids (b) Scale up techniques. (3 Hrs.)

**Books Recommended:**


### 1.3 ADVANCED MASS TRANSFER

General methods of solution of problem in unsteady state molecular diffusion in isotropic media. Derivation of equations of unsteady-state diffusion for typical cases of mass transfer in infinite, semi-infinite and finite plane media and in spherical and cylindrical media.

Mechanism of turbulent diffusion in fluids. Application of the concept of the boundary layer theory and of analogies of momentum heat and mass transfer to turbulent range diffusional phenomena. A theoretical treatment of inter relationship of mass transfer co-efficient and heat transfer – co-efficient.

Interphase diffusional phenomena. Steady state and unsteady state theories of diffusion in two phase systems, significance of hydrodynamic factor in mass transfer between to phases in relative motion.
Mass transfer with Chemical Reactions. Diffusion reaction equations, slow reactions, fast reactions, transition from low to fast reaction, problems in practice.

Books Recommended:


1.4 CHEMICAL ENGINEERING THERMODYNAMICS

1. Phase Equilibrium; Chemical potential, Gibbs Duhem equation & its applications, fugacity & activity, standard states, thermodynamic properties from volumetric data. (10 Hrs.)
2. Intermolecular forces; Potential energy functions, electrostatic forces, polarizability & induced dipoles, hydrogen bonds. (6 Hrs.)
3. Fugacities in gas and liquid mixtures, excess functions (Wohl’s expansion, Wilson’s equation, NRTL equation, UNIQUAC equation). (8 Hrs.)
4. Reaction equilibrium; Effect of temperature and pressure on reaction equilibrium constant, multi reaction equilibrium, multiphase equilibrium. (8 Hrs.)
5. Vapor-liquid equilibrium; Applications of excess functions to binary mixtures, VLE plots for tertiary mixtures, estimation of activity coefficients. (8 Hrs.)

Books Recommended:


1.5 ADVANCED TRANSPORT PHENOMENA


Concentration distributions in solids and in laminar flow – shell mass balances, diffusion through a stagnant gas film, Diffusion with homogenous chemical reaction and heterogeneous chemical reaction. Diffusion into a falling liquid film – chemical reaction inside a porous catalyst.

Equations of change for isothermal systems – Equation of continuity, Equation of Motion, Equations of change in curvilinear coordinates, use of equations of change to set up steady flow problems.

Equations of change for non-isothermal systems – Equation of energy – use of equations of change to set up steady state flow problems.

Equation of change for a binary mixture – Equation of continuity of a component in curvilinear coordinates.


**Books Recommended:**

**TEXT BOOKS**


**REFERENCE BOOKS**


SYLLABUS FOR  
M. E. (CHEMICAL ENGINEERING)  
SECOND SEMESTER

2.1 ADVANCED HEAT TRANSFER

1. *Analysis of Convection Heat Transfer*: Convection heat transfer, boundary layer fundamentals, conservation of mass, momentum and energy for laminar and flow over a flat plate, dimensionless Boundary – Layer equations & similarity parameters, dimensional analysis, integral equations of the laminar boundary layer, analysis between momentum and heat transfer over a flat surface; turbulent flow and turbulent boundary layers analysis, analysis for turbulent flow over a flat surface.

2. *Heat Transfer by Natural Convection*: Natural convection, temperature a velocity distribution in thermal boundary layers, governing equations of mass, momentum and energy for natural convection past vertical plane surface, approximate integral boundary layer analysis for natural convection, working correlations for various shapes, natural convection from finned surface, natural convection in enclosed spaces, natural convection from finned surfaces, mixed free and forced convection.

3. *Forced convection Inside Tubes & Ducts*: Analysis of laminar forced convection in long tube, correlations for laminar forced correction, analogy between heat and momentum transfer in turbulent flow, working correlations for turbulent forced convection, forced convection in noncircular sections.

4. *Forced Convection over Exterior Surfaces*: Flow over bluff bodies, local heat transfer coefficient distribution around cylinders, effect of various parameters on local heat transfer coefficient, heat transfer from tube bundles in cross-flow, heat transfer from non-circular sections.


   Boiling heat transfer, Pool boiling, forced convective boiling in horizontal and vertical tubes, sub cooled pool boiling, bubble departure diameter, bubble frequency, nucleation sites, effect of various parameters on boiling heat transfer coefficient.

6. Heat transfer in fixed bed, heat transfer in fluidized bed, heat transfer in cyclone heat exchanger.

7. *Heat transfer by combined conduction, convection and Radiation*: Thermocouple lead error in surface temperature measurements, heat transfer from radiating fins, the flat plat solar collector, the heat pipe.

*Books Recommended:*


2.2 DISTILLATION

1. Binary vapour-liquid equilibria, p-x-y diagrams, t-x-y diagrams, x-y diagrams, activity coefficients, relative volatility. Prediction of VLE by UNIFAC method. (3 Hrs.)

2. Graphical methods for estimating stage requirements for binary systems for one feed, two feed, one feed and one side stream with constant relative volatility. (5 Hrs.)

3. Analytical methods like Fensky and Underwood equations. Smoker equations and its applications. Methods of estimation of minimum reflux, optimized feed stage and minimum number of stages. (8 Hrs.)

4. Flash distillation for binary system. Application to multi-component mixtures and numericals. (5 Hrs.)

5. Batch distillation and its equation. Equations for multi-component mixtures and problems. (5 Hrs.)

6. Extractive and azeotropic distillation, general considerations for the choice of separating agents. (4 Hrs.)


8. Efficiencies in distillation, different methods. Tray and Hydraulic design. (2 Hrs.)

Books Recommended:


2.3 CHEMICAL REACTION ENGINEERING


Conversion and Reactor Sizing: Design equations for isothermal batch and flow systems. Applications of design equations for CSTR and plug flow reactors, Reactors in series, space time and space velocity.

Rate Laws and Stoichiometry: Relative rates of reaction, rate constant, elementary reactions, non-elementary reactions, reversible reactions, batch system stoichiometric table, flow system stoichiometric table, volume change with reaction.

Isothermal Reactor Design: Design structure for isothermal reactors, scale-up of liquid phase batch reactor data to design of CSTR, tubular reactors.
Collection and Analysis of Rate Data: Differential method and integral method of rate analysis, method of half-lives, differential reactors. Evaluation of laboratory reactors: fixed bed, stirred batch reactor, stirred contained solids reactor, continuous-stirred tank reactor, straight-through transport reactor, recirculating transport reactor. (10 Hrs.)

Multiple Reactions: Conditions for maximizing the desired product in parallel reactions. Maximizing the desired product in series reactions. Stoichiometric table using fractional conversion for multiple reactions.

Non-Isothermal Reactor Design: Energy balances: basic ideas about constant or mean and variable heat capacities, heat added to the reactor. Non-isothermal continuous flow reactors at steady state: application to the CSTR, adiabatic tubular reactor, steady state tubular reactor with heat exchange. Multiple steady states (MSS) in a CSTR.

Distribution of Residence Times for Chemical Reactors: General characteristics, measurement of RTD: pulse input and step tracer experiment. (10 Hrs.)

Catalysis and Catalytic Reactions: Steps in a catalytic reaction, synthesizing a rate law, mechanism and rate limiting steps, design of reactors for gas-solid reactions, heterogeneous data analysis for reactor design.

Diffusion and Reaction in Porous Catalysts: Molar flux, Fick’s first law, binary diffusion, diffusion and reaction in spherical catalyst pellets, estimation of diffusion and reaction limited regimes. (10 Hrs.)


Models for Non-Ideal Reactors: One parameter models: the tank-in-series model and the dispersion model. Two parameter models: real CSTR modeled with an exchange volume and real CSTR modeled using bypassing dead space. (10 Hrs.)

Books Recommended:


2.4 ADVANCED PROCESS DYNAMICS AND CONTROL

1. A brief review of the dynamic behavior of control systems, control valves and valve characteristics. Stability of control systems by root locus method using P, PI and PID controllers, ¼ decay ratio criterion. (5 Hrs.)

2. A brief review of frequency response technique, Ziegler-Nichols controller tuning rules, Bode and Nyquist plots, Bode-Nyquist stability criterions, development of empirical models from frequency response data: Graphical methods for 1st order plus dead time and 2nd order plus dead time processes. (8 Hrs.)

3. Advanced Control Strategies:

   Cascade control: Closed loop behavior and controller design for cascade control.
   Feed forward control: Logic of feed forward control, designing of feed forward controllers, practical aspects on the design of feed forward controllers, feed forward-feed back control, ratio control.
   Feed back control systems with large dead time: Smith Predictor scheme.
   Selective Control Systems: Override control and Auctioneering control systems

Adaptive and Inferential control. (12 Hrs.)

4. Multivariable Control: State space representation of physical systems, transfer function matrix, interaction of control loops, relative gain array and selection of loops, design of non-interacting control loops: Decouplers. (8 Hrs.)

5. Model based control: Direct synthesis method (DSM)-controller design based on process model and desired closed loop transfer function. Internal Model Control- basic structure of IMC, design of internal model controller (IMC) and conventional feedback controller. (5 Hrs.)

6. Digital control: Introduction to direct digital control (DDC), sampling continuous signals and its reconstruction. (2 Hrs.)

Books Recommended:


2.5 PROCESS MODELLING AND SIMULATION

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 – Simple
vs. rigorous. Lumped parameter vs. distributed parameter; Steady state vs. dynamic, Transport phenomena based vs. Statistical, empirical vs analytical. Concept of degree of freedom analysis.

Review of numerical methods used for solution of; linear and non linear equations, ODE’s and PDE.

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, evaporators, etc.

Unsteady state lumped systems: models giving rise to differential algebraic equations (DAE) with applications of laws of conservation of mass, momentum and energy. Analysis of liquid level tank, gravity flow tank, jacketed stirred tank heater, reactors, Flash separation column, multistage batch and continuous distillation column, Absorption and Extraction columns.

Unsteady State Distributed Systems: Analysis of laminar flow in pipe, heat exchanger, packed columns, plug flow reactor, packed bed reactor, absorption and extraction in packed beds.

Books Recommended:

TEXT BOOKS


REFERENCE BOOKS


2.5.1 PROCESS MODELLING AND SIMULATION (PRACTICALS)

Practicals based on theory covered in Paper 2.5.