# IPS ACADEMY INDORE

## INSTITUTE OF ENGINEERING & SCIENCE

(AN AUTONOMUS INSTITUTE BY UGC)

## DEPARTMENT OF CHEMICAL ENGINEERING

## I & II SEMESTER SCHEME & SYLLABYS

## M. Tech. in Chemical Engineering

## (Specialization in Computer Aided Design)

**Semester I (First Year)**

| S.No. | Course Code | Course Title | Hrs./ week | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1 | PSCC-MTCH101 | Computer Aided Design of Mass Transfer Equipment | 3 | 1 | 0 | 4 |
| 2 | PSCC-MTCH102 | Design of Chemical Reactor | 3 | 1 | 0 | 4 |
| 3 | PSEC-MTCH101 | Program Specific Elective Course-I | 3 | 0 | 0 | 3 |
| 4 | PSEC-MTCH102 | Program Specific Elective Course-II | 3 | 0 | 0 | 3 |
| 5 | LC-MTCH101 | Computer Aided Design of Mass Transfer Equipment Lab | 0 | 0 | 4 | 2 |
| 6 | LC-MTCH102 | Design of Chemical ReactorLab | 0 | 0 | 4 | 2 |
| 7 | MLC-MTCH101 | Fundamentals & Basic Design of Chemical Processes | 2 | 0 | 0 | 2 |
| 8 | AUC-MTCH101 | Audit Course-I | 2 | 0 | 0 | 0 |
| | | **Total** | **16** | **02** | **08** | **20** |
| | | **Total academic engagement and credits** | **26** | | | **20** |

| **Program Specific Elective Course-I** | **Program Specific Elective Course-II** | **Audit Course-I** |
|---|---|---|
| CFD Applications in Chemical Processing | Modeling & Simulation of Chemical Engineering System | Business Communication |
| Novel Separation Process | Interfacial Science and Engineering | Economics Policies in India |
| Advanced Transport Phenomena | Statistical Design and Analysis of Experiments | Stress Management |
| Fundamentals of Adsorption and Catalysis | Multi-component Separations | Constitution of India |

**Semester II (First Year)**

| S. No. | Course Code | Course Title | Hrs./ week | | | Credits |
|---|---|---|---|---|---|---|
| | | | **L** | **T** | **P** | |
| 1 | PSCC-MTCH201 | Computer Aided Design of Heat Transfer Equipment | 3 | 1 | 0 | 4 |
| 2 | PSCC-MTCH202 | Advanced Process Dynamics & Control | 3 | 1 | 0 | 4 |
| 3 | PSEC-MTCH201 | Program Specific Elective Course-III | 3 | 0 | 0 | 3 |
| 4 | OEC-MTCH201 | Open Elective Course | 3 | 0 | 0 | 3 |
| 5 | LC-MTCH201 | Computer Aided Design of Heat Transfer EquipmentLab | 0 | 0 | 4 | 2 |
| 6 | LC-MTCH202 | Advanced Process Dynamics & ControlLab | 0 | 0 | 4 | 2 |
| 7 | MLC-MTCH201 | Research Methodology & IPR | 2 | 0 | 0 | 2 |
| 8 | AUC-MTCH201 | Audit Course-II | 2 | 0 | 0 | 0 |
| | | **Total** | **16** | **02** | **08** | **20** |
| | | **Total academic engagement and credits** | **26** | | | **20** |

| **Program Specific Elective Course-III** | **Open Elective Course** | **Audit Course-II** |
|---|---|---|
| Introduction to Micro-fluidics and Micro-reactors | Energy Conservation & Audit | Soft Skills and Interpersonal Communication |
| Multiphase Reactor Engineering | Industrial Safety& Hazard Management | Communication Skills |
| Design of Piping Systems | Waste to Energy | Disaster Management |
| Advanced Nanotechnology | Composite Materials | |

| Course Code | Semester | Course Title | Load | Credit |
|---|---|---|---|---|
| PSCC-MTCH101 | I | Computer Aided Design of Mass Transfer Equipment | L-3, T-1, P-4 | 6 |

**Course objective-**To impart knowledge about design principles and CAD of various mass transfer equipment.

**Course content-**

**MODULE 1:**Introduction: Introduction of computer aided design (CAD) a review of tools for CAD. Scope of computer aided design of process equipment. The techniques of digital simulation, Construction of Information flow Diagram and encoding IFD into various numerical forms.

**MODULE 2:**Basic Design Principles and Methods:Ideal-liquid-solution models, non-ideal thermodynamic property models, and activity-coefficient models for liquid phase. Design variables and their influence on multicomponent separation processes, short cut design methods for absorption, stripping, extraction and distillation column.

**MODULE 3:**Multicomponent Separation Processes and CAD of Staged Columns: Separation of multicomponent mixtures by use of a single equilibrium stage, flash calculation under isothermal and adiabatic conditions, tri-diagonal formulation of component material balances and equilibrium relationships for distillation, absorption and extraction of multicomponent systems. Design of absorbers, distillation columns, strippers and extractors.

**MODULE 4:**Tray Hydraulics: Tray hydraulics and design considerations for various trays.

**MODULE 5:**Packed Columns: CAD of packed absorber, extractor and distillation column using different pickings. CAD of pressure-swing adsorption system.

**Text/Reference Book-**


1. Sinnott R.K. and Towler G., (2009) Chemical Engineering Design, 5th Ed., New York, Butterworth-Heinemann.
2. Seader J.D. and Henley E.J.,(2011) Separation Process Principles, 3rd Ed., Hoboken, New Jersey, John Wiley & Sons
3. Holland C.D.,(1975) Fundamentals and Modeling of Separation Processes, New Jersey, Prentice Hall.
4. Stichlmair J.G. and Fair J.R., (1998) Distillation Principles and Practices, Hoboken, New Jersey, John Wiley & Sons.


**List of experiments-**

1. Simulate the batch distillation column.
2. Simulate the flash column.
3. Simulate liquid-liquid extraction problem.

4. For a binary/multicomponent system calculate the Bubble P, Dew P, Bubble T and Dew T.
5. For a binary system involving one user define component from the data bank, generate VLE data and plot T-x-y and P-x-y plots.
6. Simulate mixer with input streams (two are more) and one output streams.
7. Simulate flow splitter with one input stream and two or more streams.
8. Simulate the flash column.
9. Design a binary distillation column and simulate it (shortcut column followed by redfrac column).

| Course Code | Semester | Course Title | Load | Credit |
|---|---|---|---|---|
| PSCC-MTCH102 | I | Design of Chemical Reactor | L-3, T-1, P-4 | 6 |

**Course objective-**To provide advanced knowledge of reaction kinetics and chemical reactors.

**Course content-**

**MODULE 1:**Review of design of ideal isothermal homogeneous reactors for single and multiple reactions.

**MODULE 2:** Residence time distribution (RTD) of ideal reactors, interpretation of RTD data, flow models for non-ideal reactors – axial dispersion, N tanks in series, and multiparameter models, influence of RTD and micro-mixing on conversion.

**MODULE 3:** Adiabatic and non-adiabatic operations in batch and flow reactors, optimal temperature progression, hot spot in tubular reactor, autothermal operation and steady state multiplicity in continuously stirred tank reactor and tubular reactors.

**MODULE 4**: Introduction to multiphase catalytic reactors, effectiveness factor, selectivity, catalyst deactivation, use of pseudo-homogeneous models for design of heterogeneous catalytic reactors (fixed and fluidized beds).

**MODULE 5:** Gas-liquid-solid reactors, hydrodynamics and design of bubble column, slurry and trickle-bed reactors.

**Text/Reference Book-**

1. Fogler H.S., 4th Ed,2006, Elements of Chemical Reaction Engineering, Prentice-Hall.
2. Levenspiel O.3rd Ed.1999, Chemical Reaction Engineering, Wiley.

**List of experiments-**

1. Determine the specific reaction constant in CSTR reactor.
2. Evaluate the specific reaction constant in Plug Flow reactor.
3. Calculate the conversion in cascade system.
4. Find out the order of reaction in CSTR reactor.
5. Calculate reaction time in batch reactor.
6. Calculate conversion in CSTR Reactor.
7. Study the non-isothermal behavior of reactor.
8. Study RTD behavior of Reactor.

| Course Code | Semester | Course Title | Load | Credit |
|---|---|---|---|---|
| PSEC-MTCH101 | I | Program Specific Elective Course-I | L-3, T-0, P-0 | 3 |

## CFD Applications in Chemical Processing

**Course objective-**

**Course content-**

**MODULE1:** Introduction to Computational Fluid Dynamics (CFD) and modeling of flow; Summary of governing equations; Conservation form of equations; Well-posed and ill-posed problems.

**MODULE 2:** Discretization of the equations; Truncation and Round-off error; Explicit and Implicit approaches; Concepts of numerical or artificial viscosity; Different boundary conditions. Application of Finite Difference methods to wave equations, Laplace equations and Burgers equation; Stability considerations.

**MODULE 3:** Numerical methods for boundary layer type equations, Navier Stokes equations; Outline of MAC and SIMPLE algorithms. Grid generation; Concepts of Finite volume methods.

**MODULE4:** Solution of Flow with coupled heat transfer (forced and natural convection); Outline of Reactive flow (combustion) and multi-phase flow. Introduction of a commercial CFD package (FLUENT).

**Text/Reference Books:**

1. Computational Fluid Mechanics and Heat Transfer by D. A. Anderson, J. C. Tannehill and R. H. Pletcher.
2. Numerical Heat transfer and and Fluid Flow by S. V. Patankar
3. Computational Fluid Dynamics by P. J. Roache4. Computational Methods for Fluid Flow by R. Peyret and T. D. Taylor.

## Novel Separation Process

**Course objective-**The objective of this course is to understand basic principles of various novel separation process applied in chemical industries and their application with case studies.

**Course content-**

**MODULE 1:** Mechanisms of mass transport, steady and molecular diffusion, equimolar counter diffusion, diffusion as a mass flux, thermal diffusion, multicomponent gas phase system: molar flux in terms of effective diffusivity, maxwell’s law of diffusion, diffusivities in solids liquids, gases. steady state molecular diffusion in fluids at rest and in laminar flow, unsteady state diffusion.

**MODULE 2:** Mass transfer in turbulent flow- eddy diffusion and Prandtl mixing length, mass transfer through a phase boundary two film theory, penetration theory, film penetration theory, surface renewal theory, diffusion in liquids. velocity in mass transfer. mass transfer in turbulent flow: Reynolds analogy, Chilton Colburn analogy.

**MODULE 3:** Boundary layer: introduction, momentum equation, the turbulent boundary layer: the turbulent portion, the laminar sub layer, boundary layer theory applied to a pipe flow: entry conditions, application of the boundary layer theory.

**MODULE 4:** Principle of membranes separation process, classification characterization and preparation of membrane, membranes modulus and application, liquid membranes and industrial application.

**MODULE 5:** Ternary and multicomponent system fractionation theories: multicomponent mixture: equilibrium data, feed and product composition, light and heavy key components, calculation of a number of plates required for a given separation, minimum reflux ratio, number of plates at total reflux, relation bet reflux ratio and no of plates. brief description about azeotropic and extractive distillation.

**Text/Reference Book-**


1. C.J.Geankoplis, Transport Processes and Unit Operations, Prentice-Hall of India Pvt. Ltd., New Delhi, 2000.
2. J. M. Coulson and J.F. Richardson, Chemical Engineering, Fluid Flow, Heat Transfer and Mass Transfer, Vol -1, 1998, Elsevier India
3. R.E. Treybal, Mass-Transfer Operations, McGraw-Hill, New York, 1980.
4. C.J. King, Separation Processes, Tata McGraw Hill, New Delhi, 1982.
5. J.D. Seader and E J.Henley, Separation Process Principles, John Wiley & Sons, 1998.


## Advance Transport Phenomena

**Course objective-**To provide advanced concepts of momentum, mass and heat transfer operations develop detail designing of various types’ chemical engineering process equipment.

**Course content-**

**MODULE 1:**Review of basic principles and equations of change in transport of momentum, heat and mass; Viscosity, thermal conductivity and diffusivity; Shell balance for simple situations to obtain shear stress, velocity, heat flux, temperature, mass flux and concentration distributions.

**MODULE 2:** Equations of continuity, motion, mechanical energy, angular momentum, energy, and equation of continuity for multicomponent mixture. Use of the equations of change in solving problems of momentum, heat and mass transport, dimensional analysis of the equation of change.

**MODULE 3:** Unsteady state flow, heat and mass transfer problems, creeping flow around a sphere, flow through a rectangular channel, unsteady heat conduction in slabs with and without changing heat flux, heat conduction in laminar in compressible flow, potential flow of heat in solids, unsteady state diffusive mass transport, steady state transport of mass in binary boundary layers.

**MODULE 4:** Velocity, temperature and concentration distributions in smooth cylindrical tubes for incompressible fluids, empirical equations for various transport fluxes and momentum. Definitions of friction factor and heat and mass transfer coefficients; Heat and mass transfer in fluids flowing through closed conduits and packed beds; Mass transferaccompanied with chemical reaction in packed beds; Combined heat and mass transfer by free and forced convection; Transfer coefficients at high net mass transfer rate.

**MODULE 5:** Momentum, heat and mass balances and their application, use of macroscopic balances in steady and unsteady state problems; Cooling and heating of a liquid in stirred tank, start-up of a chemical reactor.

**Text/Reference Book-**

1. Bird R.B., Stewart W.E. and Lightfoot E.N., "Transport Phenomena", 2nd Ed., Wiley, 1994.
2. Leal L.G., "Advanced Transport Phenomena: Fluid Mechanics and Convective Transport Processes", Cambridge University Press, 2007.
3. Dean W.M., "Analysis of Transport Phenomena", 2 nd Ed, Oxford University Press, 2012.
4. Brodkey R.S. and Hershey H.C., "Transport Phenomena – A Unified Approach", Brodkey.2003.

## Fundamentals of Adsorption and Catalysis

**Course objective-**The objective of this course is to understand basic principles of adsorption and catalysis and role of these processes in chemical industries and their application.

**Course content-**

**MODULE 1:** Evolution of adsorption as a separation technique. Adsorption versus other separation techniques. Fundamental factors influencing adsorption of solutes. Adsorption equilibria and kinetics: Typical isotherms in single and multicomponent systems: Freundlich, Langmuir, IAST, Sips. Heat of adsorption, Physical and Chemical adsorption.

**MODULE 2:** Adsorber Design: Modelling the dynamics of batch and continuous adsorption processes. Design of adsorbers. Engineered adsorbents: Natural adsorbents, Procedures involved in the synthesis, activation and functionalization of adsorbents such as activated carbon, activated alumina, synthetic zeolites and carbon nanotubes.

**MODULE 3:** Regeneration of spent adsorbents. Analysis of adsorbents: Characterization of adsorbents and interpretation of results from the use of SEM, BET, FTIR and XRD instruments. Applications of adsorption: Choice of adsorbent and adsorption processes for different separation problems encountered in chemical, pharmaceutical and environmental applications Current and future trends: Advances in adsorbents and adsorption processes.

**MODULE 4:** Catalysis: concepts – evolution, model catalytic reactions for elucidation; ethylene hydrogenation, CO oxidation and hydrocarbon reactions.

**MODULE 5:** Review of catalysis: Concepts like multiple theory, ensembles, geometric factor; local field effects; coupled interactions; structure sensitivity and structure insensitivity.Heterogeneous catalysis and effectiveness factors; Non-catalytic gas-solid reactions: shrinking core model

**Text/Reference Book**


1. F. Froment, K.B. Bischoff and J. de Wilde (2011), Chemical Reactor Analysis & Design, 3rd Ed., John Wiley & Sons.
2. E. Davis and R.J. Davis (2003), Fundamentals of chemical reaction engineering, McGraw-Hill.
3. Seader, J.D., E. J. Henley, and D. K Roper: Separation Process Principles with Applications Using Process Simulators, 4th edition (2016)., John Wiley & Sons, New Jersey, 2016.
4. Worch, E.: Adsorption Technology in Water Treatment Fundamentals, Processes and Modeling (2012), De Gruyter, Berlin.
5. Yang, R. T.: Adsorbents Fundamentals and Applications (2003), John Wiley and Sons, New Jersey.
6. Fogler H. S., Elements of Chemical Reaction Engineering, Prentice Hall.

| Course Code | Semester | Course Title | Load | Credit |
|---|---|---|---|---|
| PSEC-MTCH102 | I | Program Specific Elective Course-II | L-3, T-0, P-0 | 3 |

## Modeling & Simulation of Chemical Engineering System

**Course objective-**To study the modeling and simulation of chemical processes

**Course content-**

**MODULE 1:**Introduction to modeling, a systematic approach to model building, classification of models. Conservation principles, thermodynamic principles of process systems

**MODULE 2:**Development of steady state and dynamic lumped and distributed parameter models based on first principles.

**MODULE 3:**Development of grey box models. Empirical model building. Statistical model calibration and validation. Population balance models. Examples. Solution strategies for lumped parameter models. Stiff differential equations.

**MODULE 4:**Solution methods for initial value and boundary value problems. Euler's method. R-K method shooting method, finite difference methods. Solving the problems using MATLAB library package.

**MODULE 5:**Solution strategies for distributed parameter models. Solving parabolic, elliptic and hyperbolic partial differential equations. Finite element and finite volume methods

**Text/Reference Book-**


1. Hangos K.M and I.T. Cameron (2001) Process Modelling and Model Analysis, Academic Press.
2. Luyben W.L. (1990) Process Modelling Simulation and Control for Chemical Engineers, 2nd Edn., New York. McGraw Hill Book Co.
3. Mark E. Davis (1984) Numerical Methods and Modelling for Chemical Engineers, John Wiley & Sons.
4. Singiresu S. Rao (2002) Applied Numerical Methods for Engineers and Scientists, NJ. Prentice Hall publication


## Interfacial Science and Engineering

**Course objective-**Develop a broad background in interfacial science which will enable students to understand much of the otherwise specialized contemporary published research in nanoparticles and surfaces and apply these themes to their own research and development problems effectively.

**Course content-**

**MODULE 1:** Introduction to the engineering of interfaces; Definitions of fluid-fluid and fluid-solid interfaces; Occurrence of interfaces in science and engineering; Overview of industrial applications of various interfacial phenomena; Colloidal materials; Properties of colloidal systems; Experimental characterization of colloidal dispersions.

**MODULE 2:** Surface and interfacial tension; Theoretical methods for the calculation of surface and interfacial tension; Experimental techniques for the determination of equilibrium and dynamic tension; Shape of the surfaces: curvature and radius of curvature; Young Laplace equation; Kelvin equation; Pendant and sessile drops; Adams-Bashforth equation; Characterization of fluid-solid interfaces; Contact angle and wetting phenomena; Young-Dupré equation; Measurement of equilibrium and dynamic contact angles; Deposition of thin films; Mechanism of film nucleation; Chemical vapor deposition, molecular beam epitaxy, sputtering and atomic layer deposition techniques; Applications of fluid-solid interfaces in crystallization, development of ceramic materials, catalysts, electronic products and nanomaterials.

**MODULE 3:** Introduction to intermolecular and surface forces; van der Waals forces; Electrostatic double layer force; Disjoining pressure; DLVO theory; Non-DLVO forces. Interfacial rheology and transport processes; Surface shear viscosity; Surface dilatational viscosity; Boussinesq number; Interfacial tension gradient and Marangoni effect; Gibbs and Marangoni elasticity; Boussinesq-Scriven model; Interfacial turbulence; Motion of drops in a liquid; Thin liquid films; Disjoining pressure and body-force models; Stability of thin liquid film; Black films.

**MODULE 4:** Adsorption at fluid-fluid and fluid-solid interfaces; Adsorption of surfactants; Gibbs and Langmuir monolayers; Gibbs adsorption equation; Surface equation of state; Surface pressure isotherm; Langmuir-Blodgett films and their applications; Radiotracer and neutron reflection techniques for studying adsorption at fluid-fluid interfaces; Henry, Freundlich, Langmuir, Frumkin and Davies adsorption isotherms; Brunauer-Emmett-Teller theory of adsorption; Adsorption hysteresis; Characterization of adsorption at fluid-solid interfaces by vacuum and non-vacuum techniques. Emulsions: Preparation, characterization and applications; Ostwald ripening; Flocculation and coalescence; Microemulsions: characterization and properties; Stability of microemulsions; Foams: preparation, characterization and stability; Structure of foams.

**MODULE 5:** Interfacial reactions; Reactions at fluid-solid interfaces; Langmuir-Hinshelwood model; External and internal transport processes; Interfacial polycondensation reactions; Fast and instantaneous reactions at fluid-fluid interfaces; Reactions at bio-interfaces; Micellar catalysis; Phase transfer catalysis. Biological interfaces; Adsorption of proteins at interfaces; Bio-membranes; Interfacial forces at bio-interfaces; Adhesion and fusion phenomena; Bio-materials.

**Text/Reference Book-**

1. Adamson,A. W. and Gast,A.P.,Physical Chemistry of Surfaces, John Wiley, New York, 1997.

2. Ghosh,P, Colloid and Interface Science,PHI Learning Pvt. Ltd., New Delhi, 2009.
3. Hiemenz,P. C. and Rajagopalan, R.,Principles of Colloid and Surface Chemistry, Marcel Dekker, New York, 1997.
4. Stokes, R. J. and Evans, D. F., Fundamentals of Interfacial Engineering, Wiley-VCH, New York, 1997.
5. Baszkin,A. and Norde, W.,Physical Chemistry of Biological Interfaces, Marcel Dekker, New York, 2000.
6. Edwards, D.A.,Brenner, H. and Wasan, D. T., Interfacial Transport Processes and Rheology, ButterworthHeinemann,Boston, 1990.
7. Hunter, R. J., Foundations of Colloid Science, Oxford University Press, New York, 2005.
8. Israelachvili, J., Intermolecular and Surface Forces, Academic Press, London, 1992.
9. Slattery, J. C., Interfacial Transport Phenomena,SpringerVerlag, New York, 1990.

## Statistical Design and Analysis of Experiments

**Course Objective-**Design, execute, and interpret the results of the experiments in a scientific manner and communicate them unambiguously.

**Course content-**

**MODULE 1:** Overview of the subject, Determinate and indeterminate errors and their analyses, Presentation of experimental data.

**MODULE 2:** Random variables and continuous probability density functions Standard probability distribution functions: Normal, Student's T, chi-square and F distributions, Hypothesis Testing and confidence intervals.

**MODULE3:** Experimentation involving one variable, Analysis of Variance (ANOVA) concepts, Factorial Design of Experiments, Orthogonal experimental designs, Central composite and Box-Behnken designs, Response surface methodology.

**MODULE 4:** Multi-variable linear regression, Advanced experimental design concepts.

**Text/Reference Books-**

1. Montgomery, D. C., G.C. Runger, *Applied Statistics and Probability for Engineers*. 5th ed. New Delhi: Wiley-India, 2011.
2. Montgomery, D. C., *Design and Analysis of Experiments*. 8th ed. New Delhi: Wiley-India, 2011.
3. Myers, R. H., D. C. Montgomery and C. M. Anderson-Cook, *Response Surface Methodology*. 3rd ed. New Jersey: Wiley, 2009.
4. Ogunnaike, B. A., *Random Phenomena*. Florida: CRC Press, 2010

## Multi Component Separation

**Course objective-**To teach student basics of multi-component mass transfer, properties of nonideal mixtures and design of multicomponent stage separation processes - distillation, extraction, adsorption and ion-exchange, membrane separation and other new separation processes.

**Course content-**

**MODULE 1:** Overview of multi-component separation: challenges;Non-ideal solution and properties, Equation of state, multicomponent vapor-liquid equilibria: Ideal mixtures at low pressures - Non-ideal mixtures Multi component distillation design- short cut method, Fenske Underwood-Gilliland Method.

**MODULE 2:** Rigorous calculation - sum rate, boiling point and Newton's method, Sorel method and its versions in distillation column design Inside-out method, Design of distillation, absorption and extraction column/contacting devices for multi component systems.

**MODULE 3:** Choice of column– tray, the common tray types, tray capacity limits, tray hydraulics parameters, flow regimes on trays, Column sizing column, tray efficiency prediction, height and diameter of tray, packed column calculation,packing types, packing hydraulics, comparing pickings and trays packing efficiency and Scale-up.

**MODULE 4:** Design of adsorption and ion exchange column for multi-component system, Crystallization, affinity separation and chromatographic separation.

**MODULE 5:** Optimization of reflux ratio (recycle stream) and no of stages against operating cost and capital cost for all columns / contacting devices.

**Text/Reference Book-**

1. Kister, H. Z. 1992 Distillation Design, New York, McGraw-Hill.
2. Seader and Henley, (2005) Separation Process Principles, John Wiley & Sons.
3. Humphrey, J. L. and Keller, G. E. (1997), Separation Process Technology, New York McGraw- Hill.
4. King, C.J. (1982), Separation Processes, New Delhi, Tata McGraw - Hill Publishing Co. Ltd.

| Course Code | Semester | Course Title | Load | Credit |
|---|---|---|---|---|
| MLC-MTCH101 | I | Fundamental & Basic Design of Chemical Processes | L-3, T-1, P-0 | 4 |

**Course objective-**To study the basic design criteria of chemical processes and different type of process equipment’s & provide comprehensive knowledge of various process parameters and economics involved in the development of process and plant design.

**Course content-**

**MODULE 1:** General design considerations, Process design development, Layout of plant items, Flow sheets and PI diagrams, Economic aspects and Optimum design, Practical considerations in design and engineering ethics, Degrees of freedom analysis in interconnected systems, Network analysis, PERT/CPM, Direct and Indirect costs, Optimum scheduling and crashing of activities.

**MODULE 2:** Flow-sheet Synthesis, Propositional logic and semantic equations, Deduction theorem, Algorithmic flow sheet generation using P-graph theory, Sequencing of operating units, Feasibility and optimization of flow sheet using various algorithms viz, Solution Structure Generation (SSG), Maximal Structure Generation (MSG), Simplex, Branch-and-bound.

**MODULE 3:** Factors affecting Investment and production costs, Estimation of capital investment and total product costs, Interest, Time value of money, Taxes and Fixed charges, Salvage value, Methods of calculating depreciation, Profitability, Alternative investments and replacements.

**MODULE 4:** Optimum Design and Design Strategy: Break-even analysis, Optimum production rates in plant operation, Optimum batch cycle time applied to evaporator and filter press, Economic pipe diameter, Optimum insulation thickness, Optimum cooling water flow rate and optimum distillation reflux ratio.

**Text/Reference Book-**


1. Peters, M.A. and Timmerhaus, K.D.2003, Plant Design and Economics for Chemical Engineers, McGraw Hill.
2. Anil Kumar (1982), Chemical Process Synthesis and Engineering Design, Tata McGraw Hill.
3. Ulrich, G.D. (1984), A Guide to Chemical Engineering Process Design and Economics, John Wiley & Sons.

| Course Code | Semester | Course Title | Load | Credit |
|---|---|---|---|---|
| PSCC-MTCH201 | II | Computer Aided Design of Heat Transfer Equipment | L-3, T-1, P-4 | 6 |

**Course objective-**To impart knowledge about design principles and computer aided design of various heat transfer equipment.

**Course content-**

**MODULE 1:**Introduction: Basic design procedure of heat transfer equipment, overall heat transfer coefficient, shell and tube heat exchangers – construction details, selection algorithm, design codes, mean temperature difference.

**MODULE 2:** Heat Exchangers: General design considerations of shell and tubes of heat exchangers, thermo -physical properties, design of double pipe heat exchangers, tube-side heat transfer coefficient and pressure drop, shell-side heat transfer coefficient.

**MODULE 3:** Condensers: CAD of condensers for single vapors, desuperheater-cum condenser and condenser-cum-sub-cooler.

**MODULE 4:** Reboilers, Vaporizers and Evaporators: Pool boiling, convective boiling, selection and CAD of reboilers, vaporizers and evaporators.

**MODULE 5:** Computer aided design of heat transfer equipment. Design of double heat exchangers, shell and tube heat exchangers.

**Text/Reference Book-**

1. Sinnott R.K. and Towler G. 5th Ed. 2009, Chemical Engineering Design, Butterworth-Heinemann
2. McCabe W.L., Smith J.C. and Harriott P. 6th Ed.2001, Unit Operations of Chemical Engineering, New York, McGraw Hill.
3. Holman J.P. 9th Ed, 2001, Heat Transfer, New York, McGraw Hill.
4. Incropera F.P. and Dewitt D.P. 5th Ed. 2002, "Fundamentals of Heat and Mass Transfer. John Wiley.

**List of experiments-**

1. Determine the thermal conductivity of metal rod.
2. Calculate overall heat transfer coefficient & effectiveness for plate type heat exchanger.
3. Observe pool boiling phenomena and to determine the critical heat flux at different bulk temperature.
4. Determine heat transfer coefficients in drop and film condensation phenomenon.
5. Study Stefen-Boltzman constant.
6. Study forced convection by air.

7. Determine the overall heat transfer coefficient and the economy of open pan evaporator when evaporating saturation brine.
8. Study Unsteady state heat transfer by the lumped capacitance.

| Course Code | Semester | Course Title | Load | Credit |
|---|---|---|---|---|
| PSCC-MTCH202 | II | Advance Process Dynamics & Control | L-3, T-1, P-4 | 6 |

**Course objective-** Making the students aware of the sophisticated automated process plants and safety concerns and prepared for successful participation in industrial automation and safe process design and confident to handle various software /simulators (MATLAB and SIMULINK).

**Course content-**
**MODULE 1:** The notion of a system, stability, Dead time compensator, Inverted response compensator.

**MODULE 2:** Classical feedback control and controller design, loop shaping, Feed-forward and Ratio controller, and Cascade Controller.

**MODULE 3:** Internal model control (IMC), IMC based PID design, direct synthesis controller. Elements of linear system theory (system description canonical transformation state controllability and observability).

**MODULE 4:** State estimator, State feedback controller, Pole placement and observer-based controller. MIMO systems: Extent of interaction and pairing of controlled and manipulated variable using RGA and SVD analysis.

**MODULE 5:** Practical procedure of MIMO system (closed loop) design. Design of model predictive Controller (MPC).

**Text/Reference Book-**

1. H. K. Versteeg and Malalasekera, An Introduction to Computational Fluid Dynamics: The Finite Volume Method, Longman Scientific & Technical, 1995.
2. K. Muralidhar, and T. Sundararajan,Computational Fluid Flow and Heat Transfer, Narosa Publishing House, 1995.


**List of experiments-**
1. Solving linear and non-linear algebraic using MATLAB/SCILAB.
2. Differential and partial differential equations using MATLAB/SCILAB.
3. Process Identification using MATLAB/SCILAB.
4. Optimization using MATLAB/SCILAB.
5. Open loop/closed loop process simulation using MATLAB/SCILAB.
6. Use of SIMULINK for process simulation (open loop and closed loop)
7. Use of control toolbox, and MPC toolbox

| Course Code | Semester | Course Title | Load | Credit |
|---|---|---|---|---|
| PSEC-MTCH201 | II | Program Specific Elective Course-III | L-3, T-0, P-0 | 3 |

## Introduction to Micro-Fluidics and Micro Reactors

**Course objective-**To study the fundamentals of micro-scale flows and micro fabrication. design of microfluidic components and few applications of microfluidic systems.

**Course content-**

**MODULE 1:** Origin, Definition, Benefits, Challenges, Commercial activities, Physics of miniaturization, Scaling laws.

**MODULE 2:** Intermolecular forces, States of matter, Continuum assumption, Governing equations, Constitutive relations. Gas and liquid flows, Boundary conditions, Slip theory, Transition to turbulence, Low Re flows, Entrance effects. Exact solutions, Couette flow, Poiseuille flow, Stokes drag on a sphere, Time-dependent flows, Two-phase flows, Thermal transfer in microchannels. Hydraulic resistance and Circuit analysis, Straight channel of different cross-sections, Channels in series and parallel.

**MODULE 3:** Surface tension and interfacial energy, Young-Laplace equation, Contact angle, Capillary length and capillary rise, Interfacial boundary conditions, Marangoni effect.

**MODULE 4:** Materials, Clean room, Silicon crystallography, Miller indices. Oxidation, photolithography- mask, spin coating, exposure and development, Etching, Bulk and Surface micromachining, Wafer bonding. Polymer microfabrication, PMMA/COC/PDMS substrates, micro molding, hot embossing, fluidic interconnections.

**MODULE 5:** Micropumps, Check-valve pumps, Valve-less pumps, Peristaltic pumps, Rotary pumps, Centrifugal pumps, Ultrasonic pump, EHD pump, MHD pumps. Microvalves, Pneumatic valves, Thermo pneumatic valves, Thermo mechanical valves, Piezoelectric valves, Electrostatic valves, Electromagnetic valves, Capillary force valves. Micro flow sensors, Differential pressure flow sensors, Drag force flow sensors, Lift force flow sensors, Coriolis flow sensors, Thermal flow sensors. Micro mixers, Physics of mixing, Pe-Re diagram of micromixers, Parallel lamination, Sequential lamination, Taylor-Aris dispersion. Droplet generators, Kinetics of a droplet, Dynamics of a droplet, In-channel dispensers, T-junction and Cross-junction, Droplet formation, breakup and transport. Microparticle separator, principles of separation and sorting of micro particles, design and applications. Microreactors, Design considerations, Liquid-phase reactors, PCR, Design consideration for PCR reactors.

**Text/Reference Book-**


1. Patrick Tabeling, 2012, Introduction to Microfluidics Oxford University Press.
2. Nam-Trung Nguyen, Steven T. Wereley and Seyed Ali Mousavi Shaegh, 2019 Fundamentals and Applications of Microfluidic Third edition, Artech House.

3. Brian J. Kirby, 2010 Micro- and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices, Cambridge University Press.

## Multiphase Reactor Engineering

**Course objective-**Students should be able to calculate size and operating conditions required for a given multiphase reactor.

**Course content-**

**MODULE 1:** Introduction of multiphase reactor**,** Flow past immersed bodies: Drag and drag coefficients, flow through beds of solids, motion of particles through fluids, fluidization, types of fluidization and applications.

**MODULE 2:** Interaction of fluids: Mixing of a single fluid; degree of segregation, early and late mixing of fluids, Gas-liquid flow phenomenon.

**MODULE 3:** Types of Multiphase-Reactors: Various types of multiphase reactors. Gas-liquid-solid reactors eg. Packed bed, packed bubble column, trickle bed reactor, three phase fluidized bed reactor, slurry bubble column, stirred tank reactor Characteristics of above-mentioned reactors.

**MODULE 4:** RTD in Multiphase flow systems: Non-Ideal Flow: Residence time distribution of fluid in vessel, E, F & C Curve, Mean and variance, conversion in a reactor using RTD data.

**MODULE 5:** Models for multiphase reactors: Models for non-ideal flow, dispersion model, N tanks in series model.

**Text/Reference Book-**

1. Fogler H.S.2014, Elements of Chemical Reaction Engineering,4th Ed., Prentice Hall of India.
2. Levenspiel O. 2008, Chemical Reaction Engineering, 3rd Ed., Wiley-India.

# Design of Piping Systems

**Course objective-**To provide advanced concepts of types of fluids its application in different types of piping network, calculation of power losses in piping network in vertical and horizontal system.

**Course content-**

**MODULE 1:** Classification of pipes and tubes IS & BS codes for pipes used in chemical process industries and utilities.

**MODULE 2:** Pipes for Newtonian and non-Newtonian fluids, sudden expansion and contraction effects, Pipe surface roughness effects, Pipe bends, Shearing characteristics.

**MODULE 3:** Pressure drop for flow of Newtonian and non-Newtonian fluids through pipes, resistance to flow and pressure drop, effect of Reynolds and apparent Reynolds number. V Pipes of circular and non-circular cross section-velocity distribution, average velocity and volumetric rate of flow. Flow through curved pipes (Variable cross sections), effect of pipe-fittings on pressure losses.

**MODULE 4:** Non-Newtonian fluid flow through process pipes, Shear stress, Shear rates behavior, apparent viscosity and its shear dependence, Power law index, Yield Stress in fluids, Time dependent behavior, Thixotropic and rheopectic behavior, mechanical analogues, velocity pressure relationships for fluids, line.

**MODULE 5:** Pipe line design and power losses in compressible fluid flow, Multiphase flow, gas-liquid, solid - fluid, flows in vertical and horizontal pipelines, Lockhart Martinelli relations, Flow pattern regimes.

**Suggested Readings**

1. Coulson JM and Richardson J.F; Chemical Engineering - Vol I, Butterworth, Oxford
2. Govier, G.W. and Aziz K; Flow of Complex Mixtures in pipe; Krieger Pub, Florida.
3. Dean W.M., Analysis of Transport Phenomena, 2nd Ed, Oxford University Press.
4. Green DW and Malony, Perrys; Chemical Engineers Handbook; TMH.

## Advance Nanotechnology

**MODULE 1:** Basic concepts of nanoscience, scientific revolution - Feynman's vision for nanoscience, nanotechnology, and nanomaterials, classification of nanomaterials, dimensions, confinement, surface to volume ratio, energy at bulk and nano scale, nature nanophenomena, size dependent variation in mechanical, physical, chemical, electronics, reaction, catalytic properties.

**MODULE 2:** Preparation and types of nano materials, physical- chemical and mechanical methods of preparation top down approach, chemical vapor deposition, high energy balling mechano chemical reactions, mechanical alloying, nanostructure through lithography. bottom up approach: polyol route, colloidal precipitation, sol-gel process, chemical precipitation sonochemical, microbial routes, biosynthesis, electrospining method, special nanostructures, quantum dots, magnetic, metal, carbon nanomaterials, nanocomposites.

**MODULE 3:** Characterization techniques of nanomaterials, electrical, optical, mechanical and magnetic properties of nanomaterials, electrical conductivity and permittivity, magnetic permeability, Structural characterization: X-ray diffraction, electron microscopy, FTIR, XPS. Surface characterization: scanning, electron microscopy, atomic force microscopy. characterization of porous structures, characterization of quasi-static and dynamic elastic properties

**MODULE 4:** Applications of nanomaterials for research in chemical engineering nanomaterials for solar cells, energy, drug delivery, nanoscale catalysts for and automobile industries, rechargeable batteries etc.

**Text Books**

1. Nanomaterials for medical diagnosis and therapy, Challa Kumar, Wiley-VCH, 2007.
2. K.K.Jain, Nano Biotechnology, Horizon's Biosciences, 2006
3. Springer Handbook of Nanotechnology, Edited by Bharat Bhushan, Springer-Verlag (2004)
4. Nanostructures & Nanomaterials: Synthesis, Properties &Applications, G. Cao, Imperial College Press, 2004.
5. Fundamentals of Nanotechnology, Hornyak, G. Louis, Tibbals, H. F., Dutta, Joydeep, CRC Press, 2009

| Course Code | Semester | Course Title | Load | Credit |
|---|---|---|---|---|
| OEC-MTCH201 | II | Open Elective Course | L-3, T-0, P-0 | 3 |

OEC-MTCH201: Energy Conservation and Audit

**Course objective-**To understand the structure and functioning of energy management systems and to aware students on the auditing of energy management systems.

**Course content-**

**MODULE 1:** Identify the demand supply gap of energy in Indian scenario, energy management concept and objectives, energy conservation principle, energy conservation methods, energy conservation building codes, energy labeling and energy standards.

**MODULE 2:** Energy policy; energy conservation act; energy resources allocation and efficient energy use for energy conservation; energy audit instruments and their use.

**MODULE 3**: Energy efficient technologies in thermal systems: boilers and turbines; cogeneration and combined cycles; steam system and condensate systems and insulation; heat exchangers; furnaces; waste heat recovery and reuse.

**MODULE 4:** Management systems approach for energy management in organizations; energy management systems and requirements of ISO 50001.

**MODULE 5**: Auditing and certification of energy management systems: energy audit and its benefits, energy flow diagram, methodology of preliminary energy audit and detailed energy audit, energy audit report.

**Text/Reference Book-**

1. Thumann and W.J. (2003) Younger: Handbook of energy audits, Fairmont Press, Georgia, USA.
2. Sivaganaraju, S. (2012), Electric Energy Generation, Utilisation and Conservation, Pearson, New Delhi.
3. Partab H., Art and Science of utilization of Electrical Energ, Dhanapat Rai and Sons, New Delhi.
4. ISO 50001: 2011 -Energy management systems —Requirements with guidance for use.

## Industrial Safety & Hazard Management

**Course objective:** To provide comprehensive knowledge of safety and hazards aspects in industries and the management of hazards.

**Course content-**

**MODULE 1:** Introduction to industrial safety and hazards: importance of industrial safety, types of hazard: chemical hazard, thermal hazard, electrical hazard, mechanical hazard, vibrational hazard, biological hazard, radioactive hazard, safety and health standards, Indian standards and codes for safety and health.

**MODULE 2:** Relief systems: Preventive and protective management from fires and explosion-inerting, static electricity passivation, ventilation, and sprinkling, proofing, relief systems – relief valves, flares, scrubbers.

**MODULE 3:** Toxicology: hazards identification-toxicity, fire, static electricity, noise and dust concentration; material safety data sheet, hazards indices- Dow and Mond indices, hazard operability (HAZOP) and hazard analysis (HAZAN).

**MODULE 4:** Leaks and leakages: spill and leakage of liquids, vapors, gases and their mixture from storage tanks and equipment; estimation of leakage/spill rate through hole, pipes and vessel burst; isothermal and adiabatic flows of gases, spillage and leakage of flashing liquids, pool evaporation and boiling; release of toxics and dispersion. naturally buoyant and dense gas dispersion models; effects of momentum and buoyancy; mitigation measures for leaks and releases.

**MODULE 5:** Case studies: Flixborough, Bhopal, Texas, ONGC offshore, HPCL Vizag and Jaipur IOC oil-storage depot incident; Oil, natural gas, chlorine and ammonia storage and transportation hazards.

**Text/Reference Book-**


1. Crowl D.A. and Louvar J.F. 2nd Ed,2001, Chemical Process Safety: Fundamentals with Applications, Prentice Hall.
2. Mannan S. Vol.I, 3rd Ed. 2004, Lee's Loss Prevention in the Process Industries, Butterworth Heinemann.
3. Mannan S. Vol.II, 3rd Ed. 2005, Lee's Loss Prevention in the Process Industries, Butterworth Heinemann.


## Waste to Energy

**Course objective-**To deal with the various types of wastes available and technological options of their exploitation for obtaining useful energy.

**Course content-**

**MODULE 1:**Introduction: Introduction to energy from waste, characterization and classification of wastes, availability of agro-based, forest, industrial, municipal solid waste in India, proximate and ultimate analyses, heating value determination of solid liquid and gaseous fuels.

**MODULE 2:** Waste to energy options I: Incineration, pyrolysis, gasification, hydrogen production, storage and utilization, anaerobic digestion, composting: gas generation and collection in landfills.

**MODULE 3:** Waste to energy options II: Industrial liquid effluents and their energy potential, anaerobic reactor configuration for fuel gas production, separation of methane and compression.

**MODULE 4:** Densification: Densification of agro and forest wastes, technological options, combustion characteristics of densified fuels, usage in boilers, brick kilns and lime kilns.

**MODULE 5:** Biodiesel: Biodiesel production from waste/discarded oils, Case studies: Two industrial case studies where waste materials are used to supplement energy needs.

**Text/Reference Book-**

1. EL-Halwagi, M.M.1984, Biogas Technology- Transfer and Diffusion, Elsevier Applied Science.
2. Hall, D.O. and Overeed, R.P.1987, Biomass - Renewable Energy, John Willy and Sons.
3. Harker, J.H. and Backhusrt, J.R.1981, Fuel and Energy, Academic Press Inc.
4. Rogoff, M.J. and Screve, F.2011, Waste-to-Energy: Technologies and Project Implementation, Elsevier Store.
5. Young G.C.2010, Municipal Solid Waste to Energy Conversion processes, John Wiley and Sons.

## Composite Materials

**Course objective-**This subject offers the knowledge and understanding of the engineering behavior of composite materials.

**Course content-**

**MODULE 1:** Introduction to composite materials: definitions of composite material, fiber, matrix. types of fibers and raw fiber properties, types of matrix, prepegs, fillers and other additives.

**MODULE 2:** Advantages and applications: advantages of composite materials and structures. applications and use of composite materials in present world. basics of composites: mechanical behavior of composite materials. lamina, laminate: the basic building block of a composite material.

**MODULE 3:** Various types of composites: classification based on matrix material: organic matrix composites, polymer matrix composites (PMC), carbon matrix composites or carbon-carbon composites, metal matrix composites (MMC).

**MODULE 4:** Ceramic matrix composites (CMC); classification based on reinforcements: fiber reinforced composites, fiber reinforced polymer (FRP) composites, laminar composites, particulate composites, comparison with metals, advantages and limitations of composite.

**MODULE 5:** Testing of composites: mechanical testing of composites, tensile testing, compressive testing, intra-laminar shear testing, inter-laminar shear testing, fracture testing etc.

**Text/Reference Book-**

1. K.K. Chawla, 1988, Composite Materials – Science & Engineering, New York, Springer- Veslag.
2. L.J. Broutman and R.M. Krock, 1967, Modern Composite Materials, Addison-Wesley.
3. Robert M. Jones, 2015, Mechanics of Composite Materials, CRC Press Taylor & Francis.
4. David A Colling & Thomas Vasilos, vol. 2, 1995, Industrial Materials: Polymers, Ceramics and Composites, N. Jersey Prentice Hall.

| Course Code | Semester | Course Title | Load | Credit |
|---|---|---|---|---|
| MLC-MTCH201 | II | Research Methodology & IPR | L-2, T-0, P-0 | 2 |

## Course content-

**MODULE 1:** Meaning of research problem, Sources of research problem, CriteriaCharacteristics of a good research problem, Errors in selecting a researchproblem, Scope and objectives of research problem.Approaches of investigation of solutions for research problem, data collection,analysis, interpretation, Necessary instrumentations, Effective literature studies approaches, analysis, Plagiarism, Research ethics.

**MODULE 2:** Effective technical writing, how to write report, Paper, Developing a Research Proposal, Format of research proposal, a presentation andassessment by a review committee.

**MODULE 3:** Nature of Intellectual Property: Patents, Designs, Trade and Copyright, Process of Patenting and Development: technological research, innovation,patenting, development. International Scenario: International cooperation onIntellectual Property. Procedure for grants of patents, Patenting under PCT.

**MODULE 4:** Patent Rights: Scope of Patent Rights. Licensing and transfer oftechnology. Patent information and databases. Geographical Indications.New Developments in IPR: Administration of Patent System. Newdevelopments in IPR of Biological Systems, Computer Software etc.Traditional knowledge Case Studies, IPR and IITs.

## Text/Reference Book-


1. Stuart Melville and Wayne Goddard, “Research methodology: anintroduction for science & engineering students.
2. Wayne Goddard and Stuart Melville, Research Methodology: AnIntroduction.
3. Ranjit Kumar, 2nd Edition, Research Methodology: A Step by Step Guidefor beginners.
4. Halbert, Resisting Intellectual Property, Taylor & Francis Ltd ,2007.
5. Mayall, Industrial Design, McGraw Hill, 1992.
6. Niebel, Product Design, McGraw Hill, 1974.
7. Asimov, Introduction to Design, Prentice Hall, 1962.
8. Robert P. Merges, Peter S. Menell, Mark A. Lemley, Intellectual Propertyin New Technological Age”, 2016.
9. T. Ramappa, “Intellectual Property Rights Under WTO”, S. Chand, 2008


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