# Module V, T.E. Chemical Engineering

(FF 653, Issue No. 3, Rev 01 Dated 02/04/2011)

| Subject No. | Subject Code | Subject Name | Teaching Scheme (Hrs/ week) | | | Credits |
|---|---|---|---|---|---|---|
| | | | Lect. | Tutorial | Practical | |
| S1 | CH30101 | Chemical Engineering Mathematics | 3 | 0 | 0 | 3 |
| S2 | CH31101 | Mechanical Design of Equipment | 3 | 0 | 0 | 3 |
| S3 | CH30103 | Mechanical Operations | 3 | 0 | 0 | 3 |
| S4 | CH30105 | Mass Transfer Operations | 3 | 0 | 0 | 3 |
| T1 | CH30201 | Chemical Engineering Mathematics (Tutorial) | 0 | 1 | 0 | 1 |
| T2 | CH31201 | Mechanical Design of Equipment (Tutorial) | 0 | 1 | 0 | 1 |
| P1 | CH30303 | Mechanical Operations Laboratory | 0 | 0 | 2 | 1 |
| P2 | CH30305 | Mass Transfer Operations Laboratory | 0 | 0 | 2 | 1 |
| MP5 | CH37401 | Mini Project | 0 | 0 | 2 | 1 |
| PD1 | | Institute Level Elective | 0 | 0 | 2 | 1 |
| CVV3 | CH30405 | Comprehensive Viva Voce | Based on courses S2,S4 | | | 1 |
| Following course to be offered in Semester I only | | | | | | |
| SM1 | CH37301 | Seminar | 0 | 0 | 1 | 2 |
| Following course to be offered in Semester II only | | | | | | |
| PS1 | CH37302 | Project Stage I | 0 | 0 | 1 | 2 |
| | | Total | 12 | 2 | 11 | 21 |

# CH30101 :: CHEMICAL ENGINEERING MATHEMATICS

| **Credits**: 03 | **Teaching Scheme:** - Theory 3 Hrs/Week |
|---|---|

**Prerequisites**: Nil

**Objectives:**

- To introduce several computational techniques that are important in the solution of a variety of Mathematical problems that cannot be solved analytically. The sample problems will, for the most part of the course be taken from Chemical Engineering, though occasionally we will consider problems also from other related engineering areas. The methods and skills taught in this course will be valuable for future Chemical Engineering courses.
- Mapping with PEOs : 2 (a, b)

**Unit I** **(8 Hrs)**

**System of Linear Equation and Statistical Data Analysis**

**A.** Systems of linear equation using Eigen values and Eigen vector, multiple ODE, Sylvester formulae
Least square method, curve fitting and Regression (linear, multiple linear, polynomial and nonlinear)
B. Gauss Siedel method, Interpolation

**Unit II** **(8 Hrs)**

**Numerical Analysis I**

**A.** Root finding methods for algebraic equations (False position method, Newton-Raphson method), Euler's method, 2nd and 4th order Runge Kutta Method, Trapezoidal rule, Simpson's 1/3 rule, integration with unequal segments
B. Bisection method, modified Euler's method, Simpson's 3/8 rule

**Unit III** **(8 Hrs)**

**Numerical Analysis II**

**A.** Properties of finite methods (stability, convergence etc.) Finite difference method, elliptical and parabolic equations, Laplace equation, solution techniques, boundary conditions, explicit and implicit method,), Finite Volume method

B. Crank-Nicholson method, Introduction to Finite Element Methods

**Unit IV** **(9 Hrs)**

**Optimization**

**A.** Basic concept of optimization and formulation, Nature of optimization problem (constraints and unconstraint), Liner programming by simplex method.
Unconstraint Optimization problem: Global and local optimization, Region of convex or concave, Indirect methods (Newton's Method), Direct Methods (Region elimination method, Golden section method)

B. Hessian Matrix, Quasi-Newton's Method, Secant Method, Polynomial approximation (Quadratic and Cubic)

**Unit V** **(7 Hrs)**

**Tensor Analysis**

**A.** Curvilinear orthogonal system e.g. Expression in these co-ordinate systems for second order tensor such as velocity gradient

B. Newton's law of viscosity in tensorial form in Cartesian coordinates

**Text Books**


1. "Numerical Methods for Engineers", Chapra, S.C.; Canale, R.P., 4th Edition, Tata-McGraw Hill Publications, 2002.
2. "Optimization of chemical processes", Edger, T. F.; Himmelblau, D. M., McGraw-Hill, 2nd Edition, 2001.
3. "Transport Phenomena ", R.B. Bird, W.E. Stewart and E.W. Lightfoot, John Wiley.


**Reference Books**


1. "Applied Mathematics and Modeling for Chemical Engineers", Rice, R.G.; Do, D.D., John Wiley & Sons, 1995.
2. "Mathematical Methods in Chemical Engineering", Jenson, V.G.; Jeffreys, G. V., 2nd Edition, Academic Press, 1997.
3. "Applied Mathematics in Chemical Engineering", Mickley, H. S.; Shewrwood, T. S.; Reed, C. E., McGraw-Hill, 1957.
4. "An Introduction to Numerical Methods for Chemical Engineers", Riggs, James B., 2nd Edition, Texas Tech University Press, 1994.
5. "Advanced Engineering Mathematics", Erwin Kreyszig, John Wiley and sons, inc.

# CH31101 :: MECHANICAL DESIGN OF EQUIPMENTS

**Credits**: 03 **Teaching Scheme:** - Theory 3 Hrs/Week

**Prerequisites**: NIL

**Objectives:**

- To introduce the students the basic considerations in equipment design, materials of construction different types of stresses involved, design of machine elements, design of various types of equipments like pressure vessel, storage vessel, vessel supports and mixers & reaction vessels
- Mapping with PEOs : 3 (b)

**Unit I** **(8 Hrs)**

**Introduction to Design**

A. Nature of design, design factors, degrees of freedom, design variables, optimization, nature of process equipments, general design procedure, basic considerations in design, standards, codes, and their significance, fabrication techniques, equipment classification and their significance, power for rotational motion, drives for process equipments. Materials of construction. Design considerations- stresses due to static & dynamic loads, design pressure, design temperature, design stress, elastic instability, combined stresses and theories of failure, fatigue, brittle fracture, creep, temperature effect, effects of fabrication methods, economic considerations. Design of machine elements- shafts, keys & pins, couplings, packing & gaskets, stuffing box & gland
B. Joints, bearings, belts & pulleys, drives, mechanical seals.

**Unit II** **(9 Hrs)**

**Pressure Vessels**

**A.** Basics, thin & thick wall vessel, main component of vessels, proportioning of pressure vessels, selection of L/D ratio, optimum proportions of vessels.
Design of unfired pressure vessels: Types of pressure vessels, codes and standards for pressure vessels (ASME Sec VIII Div-1, 2), material of construction, selection of material, selection of corrosion allowance and weld joint efficiency, purging of vessels.
Pressure vessels subjected to internal pressure:
Complete design as per ASME Sec VIII Div-1,2 involving
Shells: cylindrical, spherical and conical,
Study, selection and design of various heads such as flat, hemispherical, torispherical, elliptical and conical,
Opening/ nozzles, oblique, nozzles and manholes, nozzle sizing, nozzle opening reinforcement calculations etc.
Flanged joints:
Gasket: Types, selection, and design.
Bolt design and selection.
Flange dimensions and optimization for bolt spacing.
Flange rating calculation as per ASME B16.5 and B16.47
Vessel internals like demister pads, spargers, vortex breaker, baffles. Inspection and testing of pressure vessels.
B. Design of pressure vessels subjected to external pressure as per ASME Sec VIII Div-1, 2, constructional features, materials for high pressure vessels, solid walled vessels, multi shell construction, vessel closures, and jacket for vessels.

**Unit III** **(7 Hrs)**

**Design of Vessel Supports**

**A.** Types of loads on pressure vessels in addition to internal & external pressure, stresses due to weight, test loads, wind & seismic loads, attached piping, weight directly attached to vessel. Introduction and classification of supports, design of bracket or lug supports- thickness of base plate, gusset plates, column supports for brackets. Design of leg supports- base plate for channel leg support. Design of skirt supports- skirt design, skirt bearing plate, anchor bolt design, design of bolting chair.

B. Design of saddle supports- longitudinal bending moments, stress in shell at the saddle, stresses in the shell at mid-span, wear plates and stiffeners, design of saddles.

**Unit IV** **(8 Hrs)**

**Storage Vessels**

**A.** Various types of storage vessels and applications, losses in storage vessels, storage of fluids- storage of volatile & non-volatile liquids- fixed roof and variable volume tanks, Various types of roofs used for storage vessels, accessories of floating roof tank. Storage of gases- spherical vessels or hortonspheres. Design of cylindrical storage vessels as per API-650- materials, bottom design, shell design, wind girders for open-top tanks, roof curb angles, self supporting roof design, column supported roof, nozzles and mountings.

B. Design of rectangular tanks as per IS: 804- design without stiffener, design with top-edged stiffener, horizontal and vertical stiffeners, bottom plate.

**Unit V** **(8 Hrs)**

**Mixers and Reaction Vessels**

**A.** Mixers- Various types of mechanical mixers- propeller, turbines & paddles their selection, flow patterns in agitated tanks, baffling, design practices, standard geometry tank, power dissipation and discharge flow correlation, mechanical agitator design.

B. Reaction vessels- Introduction, classification, heating systems, design of vessels, study and design of various types of jackets like plain, half coil, channel, limpet oil. Study and design of internal coil reaction vessels, Heat transfer coefficients in coils.

**Textbooks**:


1. 'Joshi's Process Equipment Design', Mahajani, V.V., 4th Edition, Macmillan India, 2009.
2. 'Introduction to chemical equipment design', Bhattacharya, B.C., CBS Publications, 1985.


**Reference Books**


1. 'Chemical Engineering Vol. 6 -. Design', Coulson, J. M.; Richardson, J. F.; Sinnott, R. K., Pergamon Press, 1983.
2. 'Handbook of chemical processing equipment', Nicholas P., Butterworth-Heinemann, 2000.
3. 'Pressure Vessel Design handbook', 2nd Edition, Henry H. Bednar, Krieger Publishing Company, Florida, 1991.
4. 'Pressure Vessel Design Manual', 3rd Edition, Denis Moss, Elsevier, 2004

# CH30103 :: MECHANICAL OPERATIONS

| Credits: 03 | **Teaching Scheme:** - Theory 3 Hrs/Week |
|---|---|

**Prerequisites**: nil

**Objectives:**

- To understand the solid-fluid operations
- To understand working, principles of various mechanical operations.
- Mapping with PEOs : 3 (b)

**Unit I** **( 8 Hrs )**

**Particle Technology and size reduction**

**A**. Particle size and shape, Mixtures of particles, Determination of particle size, Standard screen series, screen analysis, Screen effectiveness and capacity, Industrial screening equipments. Crushing efficiency, energy requirement calculations by using different crushing laws, Open circuit & Closed circuit grinding.

**B**. Size reduction equipments.

**Unit II** **( 8 Hrs )**

**Storage & Different Operations of Solids**

**A**. Storage of solids, characteristics of Bulk solids. Different operations:-Froth flotation, magnetic separator, fiber and fabric filter, electrostatic precipitators, cyclone separator, hydro cyclone.

**B**. Mineral jig, scrubbers, centrifuges, centrifugal clarifier.

**Unit III** **( 8 Hrs )**

**Mixing and Transport of Solids**

**A**. Necessity of mixing & agitation in chemical industries, Calculation of power requirement of mixing equipment, Solid – Solid Mixing, Agitator selection. Conveyors: design, calculation of Screw conveyors, Belt Conveyors, Chain & Flight conveyors, Bucket elevators, Pneumatic conveyors

**B**. Mixing equipment of pastes & viscous material, Mixing equipment of free flowing solids.

**Unit IV** **( 8 Hrs )**

**Filtration:**

**A**. Filter media and filter aids, classification of filtration, pressure drop through filter cake, filter medium resistance, specific cake resistance, Continuous Filtration, Washing and dewatering of filter cakes, Centrifugal filtration.

**B**. Filtration Equipments.

**Unit V** **( 8 Hrs )**

**Fluid – Solid systems**

**A**. Motion of particles in liquid, drag force, drag coefficients, Gravity settling method: Terminal velocity, Stoke's law, free settling, sink and float method, differential settling, Sedimentation and thickening: Batch sedimentation, equipments for sedimentation, Kynch theory of sedimentation, calculation of area and depth of continuous thickeners, Fluidization: flow through packed beds, characteristics of fluidized systems, minimum fluidization velocity, types of fluidization.
**B**. Batch thickeners, and continuous thickeners, applications of fluidization technique, spouted beds and fixed bed.

**Text Books**


1. "Unit Operations of Chemical Engineering", McCabe W. L. & Smith J. C.; McGraw Publications, 5th Edition.
2. "Chemical Engineering Vol. 2", Coulson J.M. & Richardson J.F, Pergamon Press, 5th ed., 2002.


**Reference Books**


1. "Introduction to Chemical Engineering", Badger W. L. & Banchero J. T, McGraw Hill Publications, 1997.
2. "Principles of Unit Operations", Foust A.S, John Wiley & Sons, 1965.
3. "Chemical Process Equipment Selection & Design", Stanley Walas, Butterworth-Heinemann, 1990.

# CH30105 :: MASS TRANSFER OPERATIONS

| Credits: 03 | **Teaching Scheme:** - Theory 3 Hrs/Week |
|---|---|

**Prerequisites**: Nil

**Objectives:**

- Apply mass transfer fundamentals to calculate rates of mass transfer for practical situations and to identify rate-limiting processes. Students will understand the importance of diffusion in Mass transfer Operations, Mass transfer without Chemical reaction. Develop familiarity with major chemical process separations units
- Mapping with PEOs : 3 (b)

**Unit I** **(8 Hrs)**

**Introduction to Mass Transfer and Molecular Diffusion**

**A.** Introduction to Mass Transfer Operations Molecular Diffusion in gases and liquids, diffusivities of gases and liquids, types of diffusion, Fick's and Maxwell law of diffusion, diffusion in solids, unsteady state mass transfer. Concept of diffusivity, Eddy diffusion, film theory, penetration theory, surface renewal theory, Steady state diffusion Flux transfer equations for gas and liquid phase based on steady and unsteady state equation. Empirical equations used to determine diffusivity through gas and liquid

B. Equation of continuity, Study of Raoult's law, Henrys law, Dimensional analysis for mass transfer and its applications, Simultaneous mass and heat transfer.

**Unit II** **(8 Hrs)**

**Equipment for gas liquid operation And Mass Transfer Coefficient**

**A.** Gas dispersal equipments – bubble columns, Liquid dispersal equipments – Venturi scrubbers, wetted wall columns.

Gas dispersed Sparged vessels – flow of gas velocity problems based on aeration tank as a time for sparging Gas hold up.. Liquid hold up – determination of interfacial area based on hold up and MTC. End effects and axial mixing. Determination of mass transfer coefficient through contacting equipment.

B. Tray tower Verses packed tower. Dimensional analysis for mass transfer and its applications, Simultaneous mass and heat transfer.

**Unit III** **(8 Hrs)**

**Gas Absorption**

**A.** Mechanism of gas absorption, equilibrium in gas absorption, Two film theory – concept of individual and overall mass transfer coefficient , application of mass transfer theories to absorption, absorption in wetted wall columns, values of transfer coefficient, absorption in packed tower and spray tower, calculation of HETP, HTU, NTU, calculation of height of packed and spray tower. Absorption in tray towers, absorption and stripping factors, calculation of number of trays for absorption

B. Tray efficiencies, absorption with chemical reaction.

**Unit IV** **(8 Hrs)**

**Humidification, Dehumidification and Drying**

**A.** Principles, vapour-liquid equilibria, enthalpy of pure substances, wet bulb temperature relation, Lewis relation, cooling tower design – HTU, NTU concept, calculation of height of cooling tower. Drying: Principles, equilibrium in drying, type of moisture binding, mechanism of batch drying, continuous drying, time required for drying, mechanism of moisture movement in solid, Design principles of tray dryer, rotary dryer, spray dryer.
**B.** Psychrometric chart , methods of humidification and dehumidification, equipment like cooling tower, spray dryer, fluidized bed and spouted bed dryer, pneumatic dryer and vacuum dryer.

**Unit V** **(8 Hrs)**

**Crystallization and Membrane Separation**

**A.** Principle rate of crystal growth, population balance and size distribution, calculation of yield, enthalpy balances, equipment.
Membrane separationtechniques. Ultra filtration. Micro filtration and reverse osmosis.
B. Batch and continuous crystallizers, Numerical based on material and enthalpy balance

**Textbooks**

1. "Mass Transfer Operations", Treybal, R.E., 3rd Edition, McGraw Hill, 1980.
2. "Chemical Engineering – Vol. I & II", Coulson J. M.; Richardson, J. F., 6th Edition, Butterworth-Heinemann, 1999.

**Reference Books**

1. "Unit Operations of Chemical Engineering", McCabe, W. L.; Smith, J. C.; Harriett, P., 4th Edition, McGraw-Hill, 1985.
2. "Perry's Chemical Engineer's Handbook", Perry, Robert H.; Green, Don W., 6th Edition, McGraw-Hill, 1984.

# CH30201 :: CHEMICAL ENGINEERING MATHEMATICS (Tutorial)

**Credits: 01** **Teaching Scheme: - Tutorial** 1 Hr/Week

**Prerequisites**: : Nil

**Objectives:**

- To solve complex chemical engineering problems using numerical techniques.
- Solve problems in Chemical Engineering Mathematics
- Mapping with PEOs : 2 (a,b)

**List of Contents**

Solution of Numerical based on Unit I to Unit V from Chemical Engineering Mathematics course.

**Text Books**


1. “Numerical Methods for Engineers”, Chapra, S.C.; Canale, R.P., 4th Edition, Tata-McGraw Hill Publications, 2002.
2. “Optimization of chemical processes”, Edger, T. F.; Himmelblau, D. M., McGraw-Hill, 2nd Edition, 2001.
3. “Transport Phenomena ", R.B. Bird, W.E. Stewart and E.W. Lightfoot, John Wiley.


**Reference Books**


1. “Applied Mathematics and Modeling for Chemical Engineers”, Rice, R.G.; Do, D.D., John Wiley & Sons, 1995.
2. “Mathematical Methods in Chemical Engineering”, Jenson, V.G.; Jeffreys, G. V., 2nd Edition, Academic Press, 1997.
3. “Applied Mathematics in Chemical Engineering”, Mickley, H. S.; Shewrwood, T. S.; Reed, C. E., McGraw-Hill, 1957.
4. “An Introduction to Numerical Methods for Chemical Engineers”, Riggs, James B., 2nd Edition, Texas Tech University Press, 1994.
5. “Advanced Engineering Mathematics”, Erwin Kreyszig, John Wiley and sons, inc.

# CH31201 :: MECHANICAL DESIGN OF EQUIPMENTS (Tutorial)

| **Credits**: 01 | **Teaching Scheme:** - Tutorial 1 Hr/Week |
|---|---|

**Prerequisites**: NIL

**Objectives:**

- To introduce the students the basic considerations in equipment design, materials of construction different types of stresses involved, design of machine elements, design of various types of equipments like pressure vessel, storage vessel, vessel supports and mixers & reaction vessels.
- Mapping with PEOs : 3 (b)

**List of Contents**

**A TERM-WORK containing the record of the following:**

1. Assignments (Any three of the following)
    a. Problems on introduction to design
    b. Problems on pressure vessel design.
    c. Problems on vessel support design.
    d. Problems on design of storage tanks.

2. Half Imperial Size Drawing Sheets (Any two of the following)
    a. Design of pressure vessels.
    b. Design of skirt support.
    c. Design of storage tanks
    d. Design of mixer.

**Textbooks**:


1. 'Joshi's Process Equipment Design', Mahajani, V.V., 4th Edition, Macmillan India, 2009.
2. 'Introduction to chemical equipment design', Bhattacharya, B.C., CBS Publications, 1985.


**Reference Books**


1. 'Chemical Engineering Vol. 6 -. Design', Coulson, J. M.; Richardson, J. F.; Sinnott, R. K., Pergamon Press, 1983.
2. 'Handbook of chemical processing equipment', Nicholas P., Butterworth-Heinemann, 2000.
3. 'Pressure Vessel Design handbook', 2nd Edition, Henry H. Bednar, Krieger Publishing Company, Florida, 1991.
4. 'Pressure Vessel Design Manual', 3rd Edition, Denis Moss, Elsevier, 2004

# CH30303 :: MECHANICAL OPERATIONS LABORATORY

| Credits: 01 | **Teaching Scheme: -** Laboratory 2 Hrs/Week |
|---|---|

**Prerequisites**: Nil

**Objectives:**

- To get hands on experience of different unit operations and should be able to handle them efficiently and independently.
- Mapping with PEOs : 3,5 (b,c)

**List of Practical (ANY 8)**

1. Properties of solids: To determine Avg. Particle size, Specific surface of mixture and No. of particles in the mixture.
2. Screening: To determine the effectiveness of screen.
3. Sedimentation: To determine area of thickener by conducting batch sedimentation test.
4. Ball mill: To determine crushing law constant (by using Rittingers law, Bonds law and Kicks law).
5. Jaw Crusher: To determine crushing law constant (by using Rittingers law, Bonds law and Kicks law).
6. Vacuum Leaf Filter: To determine filter medium resistance and cake resistance by using vacuum leaf filter.
7. Cyclone Separator: To determine efficiency of cyclone separator.
8. Froth Flotation: To determine separation efficiency using froth flotation.
9. Fluidization: To determine minimum fluidization velocity and verify with Ergun Equation.
10. Drag Coefficient: To determine terminal settling velocity and compare with theoretical settling velocity.

**Text Books**


1. 'Unit Operations of Chemical Engineering', McCabe W. L. & Smith J. C.; McGraw Publications, 5th Edition.
2. 'Chemical Engineering Vol. 2', Coulson J.M. & Richardson J.F, Pergamon Press, 5th Edition, 2002


**Reference Books**


1. 'Introduction to Chemical Engineering', Badger W. L. & Banchero J. T, McGraw Hill Publications, 1997.
2. 'Principles of Unit Operations', Foust A.S, John Wiley & Sons, 1965.

# CH30305 :: MASS TRANSFER OPERATIONS

| Credits: 01 | **Teaching Scheme:** - Laboratory 2 Hrs/Week |
|---|---|

**Prerequisites**: Nil

**Objectives** :

1. To provide hands-on experience in performance of mass transfer, separations related processes and equipment.
2. To familiarize students with various methods of data gathering, analysis and reduction.
3. Mapping with PEOs : 3,5 (b,c)

**List of Practical(any 6 to 8)**

1. To calculate rate of Drying using Tray Dryer and Rotary Dryer.
2. Process of Crystallization and its Characteristics and Batch Crystallization
3. Liquid Diffusion – To calculate the Diffusion Coefficient for a liquid –liquid system
4. Winkelmann's method – To find the diffusion Coefficient of vapour in still air
5. Enhancement Factor – To find the enhancement factor for absorption with and without chemical reaction
6. Mass transfer Coefficient – To determine the Mass Transfer Coefficient for Absorption in a Packed Tower
7. Cooling Tower– To study the characteristics
8. Humidifier and Dehumidifier – To study the Characteristics
9. Interphase Mass Transfer Coefficient – To calculate the individual and overall Mass Transfer Coefficient
10. Wetted Wall Column – To find the mass transfer coefficient in a wetted wall Column
11. Assignment using ASPEN software.

**Text Books**


1. "Mass Transfer Operations", Treybal, R.E., 3rd edition, McGraw Hill, 1980.
2. "Chemical Engineering – Vol. I & II", Coulson, J. M.; Richardson, J. F., 6th edition, Butterworth-Heinemann, 1999.


**Reference Books**


1. "Unit Operations of Chemical Engineering", McCabe, W. L.; Smith, J. C.; Harriott, P., 4th ed., McGraw-Hill, 1985.
2. "Perry's Chemical Engineer's Handbook", Perry, Robert H.; Green, Don W., 6th Edition, McGraw-Hill, 1984.

# CH37301 :: SEMINAR

| Credits: 02 | **Teaching Scheme: -** Laboratory 2 Hrs/Week |
|---|---|

**Prerequisites**: Nil

**Objectives:**

- To work on a chosen topic, create a technical report and present it.
- Mapping with PEOs : 1,4,5,6 (a-e,g,i,j)

Contents:

Seminar should be based on any latest engineering topic allotted to a group of students. The topic may be defined by the guide in discussion with the group.

Students may undertake studies in research survey, literature review and analysis, synthesis, design and development, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. Topics of interdisciplinary nature may also be taken up. A detailed literature survey is expected to be carried out as a part of the work. The group of students is required to choose the topic in consultation with the Guide.

A technical report is required to be submitted at the end of the term and a presentation made based on the same. Modern audio-visual techniques may be used at the time of presentation.

**Text Books**

1. "Project Writing Manual" B.A. Bhanvase, Chemical Engineering Department, VIT, Pune

**Reference Books: Nil**

# MODULE VI

# Module VI, T.E. Chemical Engineering

(FF 653, Issue No. 3, Rev 01 Dated 02/04/2011)

| Subject No. | Subject Code | Subject Name | Teaching Scheme (Hrs/week) | | | Credits |
|---|---|---|---|---|---|---|
| | | | Lect. | Tutorial | Practical | |
| S5 | CH30102 | Process Equipment Design | 3 | 0 | 0 | 3 |
| S6 | CH30104 | Chemical Reaction Kinetics | 3 | 0 | 0 | 3 |
| S7 | CH30106 | Chemical Technology | 3 | 0 | 0 | 3 |
| S8 | CH30108 | Separation Techniques | 3 | 0 | 0 | 3 |
| T3 | CH30202 | Process Equipment Design (Tutorial) | 0 | 1 | 0 | 1 |
| T4 | CH30204 | Chemical Reaction Kinetics (Tutorial) | 0 | 1 | 0 | 1 |
| P3 | CH30304 | Chemical Reaction Kinetics Laboratory | 0 | 0 | 2 | 1 |
| P4 | CH30308 | Separation Techniques Laboratory | 0 | 0 | 2 | 1 |
| MP6 | CH37402 | Mini Project | 0 | 0 | 2 | 1 |
| PD2 | | Institute Level Elective | 0 | 0 | 2 | 1 |
| CVV4 | CH30402 | Comprehensive Viva Voce | Based on courses S5,S7 | | | 1 |
| Following course to be offered in Semester I only | | | | | | |
| SM1 | CH37301 | Seminar | 0 | 0 | 1 | 2 |
| Following course to be offered in Semester II only | | | | | | |
| PS1 | CH37302 | Project Stage I | 0 | 0 | 1 | 2 |
| | | Total | 12 | 2 | 9 | 21 |

# CH30102 :: PROCESS EQUIPMENT DESIGN

| Credits: 03 | **Teaching Scheme:** - Theory 3 Hrs/Week |
|---|---|

**Prerequisites**: NIL

**Objectives:**

- To introduce the students to design of various types of equipments like heat exchangers, plate and packed towers, filtrations equipments and auxiliary equipments, etc.
- Mapping with PEOs : 3 (b)

**Unit I** **(8 Hrs)**

**Heat Exchangers**

Introduction, process heat transfer, types of heat exchangers, codes and standards for heat exchangers, materials of construction, API scale, forced convection equation, mean metal temperature, LMTD, caloric temperatures, countercurrent & concurrent exchangers, temperature approach & cross, , counter-flow: double pipe exchangers, baffles and tie rods, tube joining methods, design of shell and tube heat exchangers as per IS: 4503 and TEMA standards i.e. shell, tube sheets, channel, channel cover, flanged joints. Condensers & reboilers. Awareness on commercial software for thermal design.

**Unit II** **(6 Hrs)**

**Evaporators & Crystallizers**

Classification of vaporizing equipment, evaporators (including different types such as kettle, thermosiphon, vertical, horizontal etc.) Chemical evaporators, natural circulation & forced circulation evaporators, the calculation of chemical evaporators, crystallizers, types of crystallizers, design considerations.

**Unit III** **(7 Hrs)**

**Tray Column Design**

Design of plate column- distillation columns, design variables in distillation, design methods for binary systems, plate efficiency, approximate column sizing, plate contactors, plate hydraulic design.

**Unit IV** **(7 Hrs)**

**Packed Column Design**

Choices of packing, types of packing, packed bed height (distillation and absorption), HETP, HTU, NTU, Cornell’s method, Onda’s method, column diameter, column internals, column auxiliaries.

**Unit V** **(7 Hrs)**

**Filters & Dryers**

Study of various types of filters like vacuum filters, pressure filters, centrifuges and rotary drum filters, design of rotary drum filters including design of drum, shaft, bearing and drive system. Types of dryers, batch type dryers, continuous dryers.

**Unit VI** **(5 Hrs)**

**Self Study- Auxiliary Process Vessels**

Study of auxiliary process vessels such as reflux drum, knockout drum, liquid-liquid and gas-liquid separators, entrainment separators, oil water separator, Decanter, gravity separator. Safety devices used in process industries, Introduction to design and engineering software.

**Text Books**


1. "Process Heat Transfer", D. Q. Kern, Tata McGraw Hill Publications, 2009
2. "Coulson & Richardson's Chemical Engineering, Volume-6", R. K. Sinnott, Elsevier Butterworth Heinemann, MA, 2005.
3. "Joshi's Process Equipment Design", V. V. Mahajani, Fourth Edition, Macmillan Publishers India ltd, 2009.


**Reference Books**


1. 'Chemical process equipment: selection and design',Walas, S. M., Butterworth-Heinemann, 1990.
2. 'Applied Process Design for Chemical and Petrochemical Plants, Vol. 1 and 2', Ludwig, E.E., 3rd Ed., Gulf Publishing Co., 1997.

# CH30104 :: CHEMICAL REACTION KINETICS

**Credits**: 03 **Teaching Scheme:** - Theory 3 Hrs/Week

**Prerequisite: Nil**

**Objectives:**

- Demonstrate the ability to quantitatively predict the performance of common chemical reactors using simplified engineering models
- Demonstrate the ability to design a set of experiments from which they determine the kinetic model of a multi-reaction system and use this information to design a commercial reactor
- Write a rate law and define reaction order and activation energy
- Mapping with PEOs : 3 (b)

**Unit I (8 Hrs)**

**Unit 1: Kinetics of homogeneous reactions**

**A.** Irreversible and reversible reactions, Equilibrium; Order and molecularity of reaction. Elementary and non elementary reactions; Stoichiometry, Fractional conversion. Rate of reaction based on all components of the reaction and their interrelation. Law of mass action, Rate Constant-Based on thermodynamic activity, partial pressure, mole fraction and concentration of the reaction components and their interrelation,

B. Temperature dependency of rate Constant -Arrhenious law, Transition state theory and collision theory. Temperature and conversion profiles for exothermic and endothermic reactions, Stable operating condition in reactors

**Unit II (8 Hrs)**

**Unit 2: Interpretation of batch reactor data**

**A.** Batch reactor concept, Constant volume Batch reactor system; Design equation for zero, first, Second irreversible and reversible reactions, graphical interpretation of these equations and their limitations, Variable volume Batch reactors. Design equation for first and second order irreversible and reversible reactions, Graphical interpretation of their limitations, Multiple reactions-stoichiometry and Rate equations for series and parallel reactions

B. Multiple reactions-stoichiometry and Rate equations for series and parallel reactions; Non elementary single reactions Development of rate expression; Chain reactions development of rate expressions

**Unit III Ideal flow reactors (8 Hrs)**

**A.** Concept of ideality, Types of flow reactors and their differences, Space-time and Space velocity, Design equation for plug flow reactor and CSTR; Design equations for first and second order reversible and irreversible constant volume and variable volume reactor

B. Graphical interpretation of these equations; Mean holding time; Development of rate expression for mean holding time for a plug flow reactor.

**Unit IV** **(8 Hrs)**

**Single and multiple reactor system**

**A.** Size comparison of single reactors; Optimum size determination; Staging of reactors, Reactors in series and parallel; Performance of infinite number of back mix reactors in series, Back mix and plug flow reactors of different sizes in series and their optimum way of staging; Recycle reactors, Optimum recycle ratio for auto-catalytic (recycle) reactors Yield and selectivity, Parallel reactions Requirements for high yield, best operating condition for mixed and plug flow reactors, Series reactions

B. Multiple reactions in CSTR and PFR reactors. Maximization of desired product rate in a plug flow reactor and back mixed reactor, product distribution in multiple reactions.

**Unit V** **(7+1 Hrs)**

**Temperature and Pressure Effects**

A. Equilibrium Conversion, Optimum temperature progression, Adiabatic and non adiabatic operations, Temperature and conversion profiles for exothermic and endothermic reactions,

B Solving problems based on POLYMATHS, ODE, Interpretation of Batch Reactor data, Series and Parallel Reactions, Sizing of Reactor Finding Tau Optimum Etc

**Text Books**


1. Levenspeil, O., 'Chemical Reaction Engineering', 3rd. edition, John Wiley & Sons, 2001.
2. Fogler, H. S., 'Elements of Chemical Reaction Engineering', 3rd Ed., PHI, 2002.


**Reference Books**


1. Walas, S. M., 'Reaction Kinetics for Chemical Engineers', McGraw Hill, 1959.
2. Smith, J.M., 'Chemical Engineering Kinetics', 3rd ed., McGraw Hill, 1987.

# CH30106 :: CHEMICAL TECHNOLOGY

| **Credits**: 03 | **Teaching Scheme:** - Theory 3 Hrs/Week |
|---|---|

**Prerequisites**: NIL

**Objectives:**

1. To understand how to prepare process flow sheet for a given reaction chemistry.
2. To learn to study scope and basic principles of various unit operations used in chemical process industry and used in plants.
3. To learn about unit process, yield and process economics to study a chemical process technology.
4. Mapping with PEOs : 3 (b)

**Unit I** **(8 Hrs)**

**Basic Concepts**

**A.** Theory of Unit operations and industrial equipment and systems used in large scale plants; Unit processes, Development of flow diagram, schematic representation and application for unit operations and unit processes.

B. Study the selection and process specific applications knowing available industrial equipment and plant accessories

**Unit II** **(8 Hrs)**

**Chlor-Alkali Industry**

**A.** Chlor-alkali chart and importance of chlor-alkali industry, manufacturing processes process economics, and plants in India and a few examples of latest technology used in other nations; Manufacturing of soda ash, caustic soda, chlorine and engineering problems.

**B**. Membrane cell, mercury cell diaphragm cell processes and electrolytic cell processes and flowsheets

**Unit III** **(8 Hrs)**

**Nitrogen industry**

**A.** Role of nitrogen in fertilizers, manufacturing of ammonia, nitric acid, urea, the above study must involves different routes adopted, limitations, advantages and disadvantages of the process; steam-reforming process technology.

**B**. Coal gasification technologies (Fixed bed (Lurgi Process)
Fluidised bed (Winkler Process)

**Unit IV** **(8 Hrs)**

**Sulfur and Sugar Industry**

**A.** Importance, manufacturing of sulfur by Frasch process, technology for the manufacturing of sulfuric acid.

Sugar Industry: Manufacture of sugar and engineering problems associated, Dextrin and starch derivatives.

**B**. detailed study and comparison between chamber and DCDA processes; process economics.

**Unit V** **(8 Hrs)**

**Phosphorus and Paper Pulp Industry**

**A.** Importance, manufacturing of super phosphate, triple super phosphate, phosphoric acid, electro thermal processes and NPK fertilizers, production of pulp, engineering problems involved, paper manufacturing from pulp, and comparison of methods of manufacturing.

**B.** Flow sheet and process for manufacture of sulfuric acid and 'phosphate rock'

**Textbooks:**

'Dryden Outline of Chemical. Technology', Rao, M. Gopala, , 3rd Edition, East West Publishers, 1997.

2. 'Shreve's Chemical Process Industries', Austin, George T., 5th Edition, McGraw-Hill, 1984.

**Reference Books:**

1. 'Chemical Process Design and Integration', Smith, R., 3rd Edition, Wiley, 2005.

2 'Unit Processes in Organic Synthesis', Groggins, P.H., 3rd Edition, McGraw-Hill Book Co., 1958.

# CH30108 :: SEPARATION TECHNIQUES

**Credits**: 03 **Teaching Scheme:** - Theory 3 Hrs/Week

**Prerequisites**: Nil

**Objectives:**

1. To present the principles of mass transfer and their application to separation and purification processes.
2. To cover graphical methods of design of Distillation columns, liquid-liquid and solid-liquid extraction.
3. Mapping with PEOs : 3 (b)

**Unit I** **(8+1 Hrs)**

**Distillation -I**

A**.** Vapour – liquid equilibria for ideal and non-ideal systems, relative volatility, methods of distillation - differential, flash, low pressure, batch rectification. Continuous rectification for binary system, multistage (tray) towers, Lewis Sorrel, McCabe Thiele, and tray efficiencies, concept of reflux, Fenske's equation, Fenske-Underwood equation, use of open steam. Partial and total Condensers, reboilers.

B. Packed towers for distillation, NTU, HTU, HETP concept and calculations, distillation column internals.

**Unit II** **(8 Hrs)**

**Distillation-II**

A. Ponchon Savarit method for multistage operations, tray efficiencies, concept of multi component distillation. Numerical problems on multi component distillation, steam distillation, positive and negative deviations from ideality, Non ideal distillation-extractive and azeotropic distillation.

B. Numerical problems based on multi component distillation and Ponchon Savarit method.

**Unit III** **(8 Hrs)**

**Liquid – Liquid Extraction**

**A:** Ternary liquid equilibria, single stage extraction, multistage crosscurrent, countercurrent and cocurrent extraction, calculations based on triangular diagrams, x – y co – ordinates and solvent free basis. Continuous countercurrent extraction with reflux, total reflux, stage efficiency

B. Continuous contact extraction in packed towers, HTU and NTU concept

**Unit IV** **(8 Hrs)**

**Solid – Liquid Extraction (Leaching)**

A. continuous counter current leaching, ideal stage equilibrium, operating time, constant and variable underflow, number of ideal stages, stage efficiencies. Problem based on Calculation of single stage and multistage leaching processes.

**B:** Leaching equipments,

**Unit V** **(8 Hrs)**

**Adsorption and Ion Exchange**

**A:** Adsorption – Basic Principle and Equilibria in adsorption. Single gases and vapors – Adsorption of liquids. Types of adsorption – Physical and Chemical Adsorption Isotherms- Langmuir and Freundlich. Introduction to pressure Swing Adsorption (PSA), and Temperature Swing Adsorption (TSA). Ion Exchange- Principles of Ion Exchange Equilibria and rate of ion exchange

B. Equipments: Continuous Contact steady state –moving bed adsorber. Techniques and applications, equipments.

**Textbooks**


1. "Mass Transfer Operations", Treybal, R.E., 3rd edition, McGraw Hill, 1980.
2. "Chemical Engineering – Vol. I & II", Coulson J.M., Richardson, J. F., 6th edition, Butterworth-Heinemann, 1999
3. **"**Multi component distillation ", D. D. Holland, Prantic Hall India.
4. "Principles of Unit Operations", A.S. Foust, L.A.Wenzel, John Wiley &sons


**Reference Books**


1. "Unit Operations of Chemical Engineering", McCabe, W. L.; Smith, J. C.; Harriett, P. 4th ed., McGraw-Hill, 1985.
2. "Perry's Chemical Engineer's Handbook", Perry, Robert H.; Green, Don W., 6th Edition, McGraw-Hill, 1984.

## CH30202 :: PROCESS EQUIPMENT DESIGN (Tutorial)

| Credits: 01 | **Teaching Scheme:** - Tutorial 1 Hr/Week |
|---|---|

**Prerequisites**: NIL

**Objectives:**

- To introduce the students to design of various types of equipments like heat exchangers, plate and packed towers, filtrations equipments and auxiliary equipments, etc.
- Mapping with PEOs : 3 (b)

**List of Contents**

**A TERM-WORK containing the record of the following:**

1. Assignments (Any three of the following)
    a. Problems on calculation of heat exchangers
    b. Problems on design of evaporators.
    c. Problems on tray column design.
    d. Problems on design of packed columns.

2. Half Imperial Size Drawing Sheets (Any two of the following)
    a. Design of heat exchangers.
    b. Design of tray tower.
    c. Design of packed tower.
    d. Design of auxiliary vessels.

**Text Books**


1. "Process Heat Transfer", D. Q. Kern, Tata McGraw Hill Publications, 2009
2. "Coulson & Richardson's Chemical Engineering, Volume-6", R. K. Sinnott, Elsevier Butterworth Heinemann, MA, 2005.
3. "Joshi's Process Equipment Design", V. V. Mahajani, Fourth Edition, Macmillan Publishers India ltd, 2009.


**Reference Books**


1. 'Chemical process equipment: selection and design',Walas, S. M., Butterworth-Heinemann, 1990.
2. 'Applied Process Design for Chemical and Petrochemical Plants, Vol. 1 and 2', Ludwig, E.E., 3rd Ed., Gulf Publishing Co., 1997.


## CH 30204 :: CHEMICAL REACTION KINETICS (Tutorial)

| Credits: 01 | **Teaching Scheme:** - Tutorial 1 Hr/Week |
|---|---|

**Prerequisites**: : Nil

**Objectives:**

- Write a rate law and define reaction order and activation energy
- Demonstrate the ability to quantitatively predict the performance of common chemical reactors using simplified engineering models
- Demonstrate the ability to regress the experimental data from which they determine the kinetic model of a multi-reaction system and use this information to design a commercial reactor.
- Mapping with PEOs : 3 (b)

**List of Contents**

**A TERM-WORK containing the record of the following:**

1. Assignments :
    a. Preparation of reaction mechanism for the non elementary reaction
    b. Preparation of reaction mechanism for the biochemical reaction derive Michelis Menton kinetics mechanism
    c. Find the overall order of the irreversible reaction using half life period data
    d. Two problems based on best arrangement of in set of series reactors

2. Polymaths program :
    a. Solving problem based on series of reaction, considering differential equationConcentration Profile of a Series Reaction
    b. Polymath Semibatch production distribution profile

**Text Books**

1. "Chemical Reaction Engineering", Levenspile O. 3rd Edition, John Wiley & Sons, 2001.
2. "Elements of Chemical Reaction Engineering" Fogler H. S. , 3rd Edition PHI, 2002.

**Reference Books**

1. "Reaction Kinetics for Chemical Engineers", Walas, S. M.McGraw Hill, 1959.
2. "Chemical Engineering Kinetics" Smith J. M. , 3rd Edition, McGraw Hill, 1987.

## CH30304 :: CHEMICAL REACTION KINETICS LABORATORY

| Credits: 01 | **Teaching Scheme:** - Laboratory 2 Hrs/Week |
|---|---|

**Prerequisites : Nil**

**Objectives:**

- Write a rate law and define reaction order and activation energy
- Demonstrate the ability to quantitatively predict the performance of common chemical reactors using simplified engineering models
- Demonstrate the ability to regress the experimental data from which they determine the kinetic model of a multi-reaction system and use this information to design a commercial reactor.
- Mapping with PEOs : 3,5 (b,c)

**List of Practical**

1. To calculate value of rate constant ‘k’ for the saponificaton of ethyl acetate with NaOH in batch reactor – I (Where M=1)
2. To calculate value of rate constant ‘k’ for the saponificaton of ethyl acetate with NaOH in batch reactor – II (Where M=2)
3. To calculate value of rate constant ‘k’ for the saponificaton of ethyl acetate with NaOH in straight tube, coli Bent Tube reactor and CSTR and PFR
4. To calculate value of rate constant ‘k’ for the saponificaton of ethyl acetate with NaOH in mixed flow reactor.
5. To calculate value of rate constant ‘k’ for the saponificaton of ethyl acetate with NaOH in mixed flow reactors in series.
6. Verification of Arrhenius law.
7. Autoclave reactor: Reaction $CO_2$ Carbonization in the reactor
8. Residence time Distribution in PFR and CSTR, Finding Dispersion Number
9. Semibatch Reactor Addition of NaOH in Ethyl acetate, Utilization of POLYMATHS for finding Behavior of products with respective of time
10. Finding $\tau$ optimum using polymaths for parallel Reactions
11. Finding conversion and rate of polymerization reactions using gravimetric method

**Text Books**


1. “Chemical Reaction Engineering”, Levenspile O. 3rd Edition, John Wiley & Sons, 2001.
2. “Elements of Chemical Reaction Engineering” Fogler H. S. , 3rd Edition PHI, 2002.


**Reference Books**


1. “Reaction Kinetics for Chemical Engineers”, Walas, S. M.McGraw Hill, 1959.
2. “Chemical Engineering Kinetics” Smith J. M. , 3rd Edition, McGraw Hill, 1987.

# CH30308 :: SEPARATION TECHNIQUES LABORATORY

| Credits: 01 | **Teaching Scheme: -** Laboratory 2 Hrs/Week |
|---|---|

**Prerequisites**: Nil

1. **Objectives:** Apply mass transfer fundamentals to study the performance of various separation devices in practical situations.
2. Analyze the performance of columns with different types of packing (e.g. Raschig rings, berl saddles, structured packings)
3. Support the separation techniques theory course by practical experience.
4. Mapping with PEOs : 3,5 (b,c)

**List of Practical**

1. Simple Distillation
2. Total Reflux
3. Steam Distillation
4. Equilibrium Diagram for Liquid – Liquid Extraction
5. Characterization of Spray Extraction Column
6. Distillation using Sieve Plate, Bubble Cap Column
7. Batch/ Continuous Leaching
8. Adsorption and Ion Exchange
9. Two assignments based on multi component distillation using ASPEN software.

**Text Books**

1. "Mass Transfer Operations", Treybal, R.E., 3rd edition, McGraw Hill, 1980.
2. "Chemical Engineering – Vol. I & II", Coulson J. M.; Richardson, J. F., 6th edition, Butterworth-Heinemann, 1999.
3. "Introduction to ASPEN " Departmental manual.

**Reference Books**

1. "Unit Operations of Chemical Engineering", McCabe, W. L.; Smith, J. C.; Harriott, P., 4th ed., McGraw-Hill, 1985.
2. "Perry's Chemical Engineer's Handbook", Perry, Robert H.; Green, Don W., 6th Edition, McGraw-Hill, 1984.

# CH37302 :: PROJECT – I

| Credits: 02 | **Teaching Scheme:** - Laboratory 2 Hrs/Week |
|---|---|

**Prerequisites**: Nil

**Objectives:**

- Student should be able to apply Chemical Engineering knowledge.
- They should learn How to Work in Team.
- They should be learn to take task (problem) and execute it.
- The aim of the project work is to carry out research and development work.
- Mapping with PEOs : 1,4,5,6 (a-e,g,i,j)

Contents:

This stage will include a report consisting of synopsis, the plan for experimental/theoretical work and the summary of the literature survey carried out till this stage.

Students may undertake studies in application chemical engineering knowledge for manufacturing project, synthesis, design and development, experimental work, testing on the product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. Topics of interdisciplinary nature may also be taken up. A detailed literature survey is expected to be carried out as a part of this work. The group of students is required to choose the topic in consultation with the Guide.

A technical report of 15 pages is required to be submitted at the end of the term and a presentation made based on the same. Modern audio-visual techniques may be used at the time of presentation.

**Text Books**

1. “Project Writing Manual” B.A. Bhanvase, Chemical Engineering Department, VIT, Pune

**Reference Books:** Nil