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Enclosure to Item No. 4.15
27.5.2009

UNIVERSITY OF MUMBAI

Revised Syllabus for the

Third Year Chemical Engineering

(Semester V & VI)

(With effect from the academic year 2009-2010)

(1)

SCHEME OF INSTRUCTIONS AND EXAMINATIONS
UNIVERSITY OF MUMBAI

COURSE: BE (CHEMICAL ENGINEERING)
YEAR: TE **SEMESTER: V**

Sr. No.	Subject	Scheme of Instructions 1 Hr Periods			Duration of Papers Hrs	Scheme of Examination				
		Lecture	Practical	Tutorial		Theory Paper	Term Work/ Assignment/Test	Practical (with Oral)	Oral	Total
5.1	Heat Transfer Operations	4	2	-	3	100	25	25	-	150
5.2	Chemical Engineering Thermodynamics-I	4	-	1	3	100	25	-	-	125
5.3	Process Equipment Design & Drawing-I	4	3	-	4	100	25	-	-	125
5.4	Solid Fluid Mechanical Operations	4	2	-	3	100	25	25	-	150
5.5	Mass Transfer Operations-I	4	2	-	3	100	25	25	-	150
5.6	Chemical Engineering Economics	4	-	-	3	100	-	-	-	100
	TOTAL	**24**	**09**	**01**	-	**600**	**125**	**75**	-	**800**

COURSE: BE (CHEMICAL ENGINEERING)
YEAR: TE **SEMESTER:VI**

Sr. No.	Subject	Scheme of Instructions 1 Hr Periods			Duration of Papers Hrs	Scheme of Examination				
		Lecture	Practical	Tutorial		Theory Paper	Term Work/ Assignment/Test	Practical (with Oral)	Oral	Total
6.1	Chemical Process-I	4	-	1	3	100	25	-	-	125
6.2	Chemical Engineering Thermodynamics-II	4	-	1	3	100	25	-	-	125
6.3	Mass Transfer Operations-II	4	2	-	3	100	25	25		150
6.4	Process Equipment Design & Drawing-II	4	3	-	4	100	25	-	25	150
6.5	Transport Phenomenon	4	-	1	3	100	25	-	-	125
6.6	Elective-I	4	-	1	3	100	25	-	-	125
	TOTAL	**24**	**05**	**04**	-	**600**	**150**	**25**	**25**	**800**

Elective-I: 1. Piping Engineering
2. Numerical Methods in Chemical Engineering
3. Optimization & Operation Research
4. Computer Aided Design

T.E. CHEMICAL (SEM-V) 3

Class: TE. Chemical Engineering		Semester: V	
5.1 Heat Transfer Operations			
Periods Per Week (60 Min)	Lectures	04	
	Practical's	02	
	Tutorials	--	
		Hours	Marks
Evaluation System	Theory Examination	03	100
	Practical with Oral Examination	-----	25
	Term Work	----	25
	Total	---	**150**

Sr. No.	Detailed Syllabus	Hours
5.1.1	Module 1	
	1.1 Introduction: Applications of heat transfer, Mechanisms of heat flow, Basic considerations. **1.2 Heat Transfer by Conduction:** Fourier's Law; Comparison with Newton's Law of Viscosity; Thermal Conductivity; Steady state Conduction: Conduction through a flat slab; Compound Resistances in series; Conduction through a thick walled Cylinder; Critical Radius of insulation; Conduction through a spherical Shell and to a particle; Unsteady state conduction: Heating or cooling of a large Slab, an infinitely long cylinder or sphere; Semi-infinite solid; Heating of particles; Systems with negligible internal resistance; Systems with Varying Fluid temperature.	10
5.1..2	Module 2	
	Individual or Surface Heat Transfer Coefficient: Concept and Definitions; Temperature Gradients; Overall Heat Transfer Coefficients (U); Resistance Form of U; LMTD; Heat Transfer Between Fluids separated by a cylindrical Wall; Wilson Plot; Fouling Factors; Typical Heat Exchange Equipment: Shell and Tube Heat Exchanger, Double Pipe Heat Exchanger; Enthalpy Balances.	06
5.1.3	Module 03	
	3.1 Forced Convection: Thermal Boundary Layer and Flow Regimes; Dimensional Analysis: Principles and Applications; Various Empirical Correlations: Graetz, Dittus-Boelter, Sieder-Tate and Colburn Equations; Estimation of Wall Temperature; Cross	10

	sections other than Circular: Equivalent Diameter. **3.2 Natural Convection** Analysis at a heated vertical wall; Use of Dimensional Analysis; Correlations for Single Horizontal Cylinders, Vertical Cylinders and Vertical Plates.	
5.1.4	Module 04	
	Heat Transfer with Phase change Condensation: Modes and Features; Theory and Derivation of Nusselt's Equation; Correlations for Vertical Surface or Tube, Vertical Plate, Single Horizontal Tube and stack of tubes; Heat Transfer to boiling liquids; Pool Boiling of saturated Liquid: Mechanisms; Nucleate Boiling; Simplified Equations to Estimate the boiling Heat Transfer Coefficient; Concept of Maximum Flux and Critical Temperature Drop.	06
5.1.5	Module 05	
	5.1 Radiation Heat Transfer: Fundamental and facts and Definition of Terms: Emissivity, Absorptivity, Black body, Grey body, Opaque body; Stefan Boltzmann Law; Kirchhoff's Law; Basic Equations for heat transfer by Radiation; Various Cases of Radiation between Two Surfaces; The Greenhouse Effect. **5.2 Heat Exchange Equipment:** Types of Heat Exchange Equipment and their utility: Shell and Tube Heat Exchanger, Plate type Exchangers, Condensers, Boilers, Calandrias, Air cooled Exchanges, Cross flow Heat Exchangers, Scraped surface Exchangers, Extended surface Heat Exchangers; Helical Coils in Agitated Vessels; Jackets on Agitated Vessels; Direct contact Exchangers; Criteria of selection; General Design for Shell and Tube Heat Exchangers; Multipass Exchangers; Kern's method and Donhue equation to estimate shell side heat transfer Coefficient; Effectiveness-NTU Method.	12
5.1.6	Module 06	
	6.1 Heat Transfer Through Extended Surfaces: Types and Application; Longitudinal and Transverse Fins; Calculations with different Boundary conditions: Fin with Insulated End, Infinitely Long Fin, Convective Losses at tip of Fin; Efficiency of Fin; Overall Heat Transfer Coefficient. **6.2 Evaporation:** Types of Tubular Evaporators: Performance: Capacity and Economy; Boiling Point Elevation; Heat Transfer	08

	Coefficients; Overall Coefficient; Enthalpy Balances for Single Effect Evaporators with negligible and appreciable Heat of Dilution; Multi-effect Evaporators: Methods of feeding, Capacity and Economy, Effect of Liquid Head and boiling point Elevation; Vapor Recompression.	

Theory Examination:

1. Question paper will comprise of 7 questions, each of 20 marks.
2. Only 5 questions need to be solved.
3. Question 1 will be compulsory and it will be based on entire syllabus.
4. Remaining questions will be mixed in nature. (for example if Q2 has part (a) from module 3 then part (b) will be from any module other than module 3.)
5. In question paper, weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

Term work:

1. A minimum of four assignments should be given at regular intervals.

Assignments Topics

a) The concept of individual Heat transfer coefficient.
b) Nusselt's Theory in condensation.
c) Kern's method for Design of Shell and Tube Heat Exchanger.
d) Multi-effect Evaporators.
Computer based Assignment Topic: Unsteady State Heat Transfer.

2. The following parameters should be considered for laboratory performance evaluation.
   a) Punctuality b) diligence c) contents of journal
3. Points nos.1 and 2 above should account for 15 marks (out of 25 marks) for term work.
4. Average of a minimum of two tests should account for 10 marks(out of 25 marks) for term work.
5. Each and every experiment should conclusively demonstrate/verify the theory. Experimental results should corroborate with theortical/estimated/reported values. The students should explain variations between observed and expected results based on technical grounds and systematic error evaluations. Each experimental report should contain a discussion of the results obtained.
6. A minimum of ten experiments should be performed.
   A suggested list is given below:

1) Thermal conductivity
2) Heat Transfer in Laminar Flow
3) Heat Transfer in Turbulent Flow
4) Heat Transfer in Natural Convection
5) Heat Transfer in Condensation
6) Stefan-Boltzman Constant
7) Emissivity Measurement
8) Heat Transfer in Finned Tube Heat Exchanger

9) Shell and Tube Heat Exchanger
10) Double pipe Heat Exchanger
11) Unsteady State Heat Transfer
12) Heat Transfer in a coil
13) Heat Transfer in Agitated Vessel
14) Plate type Heat Transfer
15) Cross Flow Heat Transfer
16) Single effect Evaporator

Text Books:

1. Coulson, J.M. et al. Coulson & Richardsons Chemical Engineering, Vol 1,4, 5,6. Ed, Butterworth Heinmenn Ltd. 1996.
2. McCabe. W.L. Smith, J.C. Harriot P. Unit Operations of Chemical Engineering, 5th Edition, McGraw Hill International Edition.
3. Kern D.Q., Process Heat Transfer, Tata McGraw Hill Ed, 1997.
4. Holman J.P., Heat Transfer. 7th Edition, McGraw Hill.
5. N. V. Suryanarayana, Engineering Heat Transfer, Penram International Publishing Pvt. Ltd.

Reference Books:

1. Perry, R.H.et. al, 'Perry's Chemical Engineers' Handbook,6th Ed., McGraw- Hill, International Edition, 1984.]
2. McKetta,J.J.et.al.'Unit Operations Handbook,Vol 1&2, Marcel Dekker,1992.
3. McKetta,J.J.et.al,Ed., 'Heat Transfer Design Methods, Marcel Dekker, 1992.
4. Walas, S.M.,'Chemical Process Equipment Selection and Design, Butterworths Heinemann,1990.
5. Gean Koplis, C.J. Transport Processes and Unit Operations, 3rd Ed. Prentice Hall of India,1997.
6. Foust, A.SET.AL, 'Principles of Unit Operations, John Wiley & Sons (Asia), 2nd ED.,1980.
7. Hewitt, G.F.et.al, 'Process Heat Transfer',CRC Press, New York,1994.

Class: TE. Chemical Engineering		Semester: V	
5.2 Chemical Engineering Thermodynamics-I			
Periods Per Week (60 Min)	Lectures	04	
	Practical's	00	
	Tutorials	01	
		Hours	Marks
Evaluation System	Theory Examination	03	100
	Practical with Oral Examination	-----	00
	Term Work	----	25
	Total	---	**125**

Detailed Syllabus

5.2.1	Module 1 1.1 Introduction 1.2 Concepts of System, surrounding, process, cycle, state and path functions, heat and work interactions, reversible and irreversible process. 1.3 Concept of internal energy and enthalpy. 1.4 First law of thermodynamics. 1.5 Application of the first law of thermodynamics to various types of processes and cycle. 1.6 Thermodynamic analysis of flow process.	09
5.2.2	Module 2 2.1 Limitations of the first law of thermodynamics and the need for the second law. 2.2 concepts of heat engine, heat pump and refrigerator. 2.3 Second law of thermodynamics. 2.4 Carnot cycle and Carnot principle.	07
5.2.3	Module 3 3.1 Clausius inequality. 3.2 Concept of Entropy. Estimating entropy of reversible and irreversible process and cycles. 3.3 Availability and lost work.	07

5.2.4	Module 4 4.1 Ideal gas and real gas behaviour. 4.2 Equations of state(EOS) Van Der Waals, Berthelot, Dietrici , Redlich-Kwong, Redlich-Kwong Redlich-Kwong soave, Virial, Peng Robinson. 4.3 Applications of the above mentioned equations of state to a pure gas. As well as to a mixture of gases.	09
5.2.5	Module 5 5.1 Definition of Helmholtz energy and Gibbs energy. 5.2 Maxwell's relations. 5.3 Various thermodynamic relations. 5.4 Joule Thompson effect and estimation of Joule Thompson coefficient For gases.	07
5.2.6	Module 6 6.1 Residual properties. Residual enthalpy and entropy. 6.2 thermodynamic charts, diagrams and its use. 6.3 Fugacity and fugacity coefficient.	07

Theory Examination:

1. Question paper will comprise of 7 questions, each of 20 marks.
2. Only 5 questions need to be solved.
3. Question 1 will be compulsory and it will be based on entire syllabus.
4. Remaining questions will be mixed in nature. (for example if Q2 has part (a) from module 3 then part (b) will be from any module other than module 3.)
5. In question paper, weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

TERM WORK

Term work consists of minimum of eight assignments and written test. There should be at least one assignment covering each of the modules mentioned above.

The distribution of the term work will be as follows:

Assignments- 10 marks
Test-10 marks
Ateendance-5 marks

(5)

TEXT BOOKS

1. Smith J.M and Van Ness H.C ; 'Introduction to Chemical Engineering Thermodynamics' 4/e , McGraw Hill, 1994.
2. Rao Y.V.C; 'Chemical Engineering Thermodynamics' ,University Press, 1997.

REFERENCE BOOKS

1. Sandler S.L; 'Chemical Engineering Thermodynamics', 2/e, John Wiley, 1989.
2. Daubert T.E ; 'Chemical Engineering Thermodynamics', McGraw Hill, International edition , 1994.
3. Glasstone; 'Thermodynamics for Chemists', Van Nostrand East-West Press,1964.
4. Walas J W; 'Phase Equilibria', Prentice Hall N J.

B

T.E. CHEMICAL (SEM-V)

Class: TE. Chemical Engineering		Semester: V	
5.3 **Process Equipment Design & Drawing-I**			
Periods Per Week (60 Min)	Lectures	04	
	Practical's	03	
	Tutorials	---	
		Hours	Marks
Evaluation System	Theory Examination	04	100
	Practical with Oral Examination	-----	-----
	Term Work	----	25
	Total	---	**125**

Sr. No.	Detailed Syllabus	Hours
5.3.1	Module 1	
	Introduction to Chemical Process Equipment Design. Nature of process equipment, General design Procedure, Basic considerations in process equipment design, Standards, codes, & their significance, equipment classification & selection, Review of stresses due to compression & tension ; bending; torsion; temperature effects; principal stresses & theories of failure, materials of construction for chemical process equipments, Design pressure, Design temperature, design stress & design loads, Significance of factor of safety, Review of fabrication techniques, Economic & Environmental considerations in the design process.	04
5.3.2	Module 2:	
	Design of Unfired Pressure Vessels: Types of pressure vessels, codes & standards for pressure vessels (IS: 2825: 1969), material of Construction, Selection of corrosion Allowance & weld joint efficiency purging of vessels. **PART A: Pressure Vessel Subjected to Internal Pressure.** Complete Design as per IS: 2825: 1969 involving Shells: Cylindrical , spherical & conical. Study, selection & design of various heads such as Flat, hemispherical, torrispherical, elliptical & conical. Openings/nozzles, oblique nozzles & manholes etc. Flanged joints: Gasket: Types, selection & design. Bolt design &selection Flange dimensions & optimization for bolt spacing. **PART B: Pressure Vessel Subjected to External Pressure.** Design of shell, heads, nozzles, flanged joints & stiffening rings	10

	as per IS: 2825: 1969 Appendix F by use of charts. Analytical approach by elastic buckling & plastic deformation. **PART C**: Assembly & detailed fabrication drawing of the complete designed pressure vessel to a recommended scale.	
5.3.3	Module 03	
	Storage Vessels: Study of various types of storage vessels and applications. Atmospheric vessels, vessels for storing volatile & non-volatile liquids. Storage of gases, Losses in storage vessels. Various types of roofs used for storage vessels, Manholes ; Nozzles and mountings. Design of cylindrical storage vessels as per IS: 803 should include base plates, shell plates, roof plates, wind girders, curb angles for self supporting and column supported roofs. Design of rectangular tanks as per IS: 804. Complete fabrication drawing for designed storage vessel to a recommended scale	08
5.3.4	Module 04	
	Agitators: Study of various types of agitators & their applications, Baffling, Power requirement for agitation. Design of agitation system which includes design of shaft based on equivalent twisting moment, equivalent bending moment and critical speed. Design of blades and Blade assembly, keys and key ways, Design of couplings like rigid flanged, split muff and flexible couplings, Study of seals and design of stuffing box and gland, Assembly and detailed drawing of designed agitator system to a recommended scale.	06
5.3.5	Module 05	
	Reaction Vessels: Introduction, Classification of Reaction Vessels, Material of construction, Heating systems, Design of Vessel, Study and design of various types of jackets like plain half coil, Channel, limbet coil as per IS: 2825, Study and design of internal coil reaction vessels, Assembly and detailed drawing of designed reaction vessel its accessories & attachments to a recommended scale.	06
5.3.6	Module 06	
	6.1 Vessel Supports: Introduction & classification of supports. Design of skirt support considering stresses due to dead weight, wind load, seismic load & period of vibration. Design of base plate, skirt bearing plate, Anchor bolts, boiling chairs & skirt shell plates. Design of Lug or bracket support , Maximum compressive load, stresses in the vessel wall due to lugs, design of stiffness and gusset plate,	08

	design of column supports for the brackets. Design of saddle supports, Ring stiffeners, Assembly and detailed design with sketches of supports (not to scale). **6.2 Inspection, Testing & Quality Management:** Inspection of equipment, Testing of equipment by using non-destructive tests like Pressure tests. Hydraulic and pneumatic Tests & application of various NDT methods which were covered in the subject Fabrication Techniques of Sem III, Concepts of ISO and Quality Management for process plant.	

Theory Examination:

1. Question paper will comprise of 7 questions, each of 20 marks.
2. Only 5 questions need to be solved.
3. Question 1 will be compulsory and it will be based on entire syllabus.
4. Remaining questions will be mixed in nature. (for example if Q2 has part (a) from module 3 then part (b) will be from any module other than module 3.)
5. In question paper, weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

TERM WORK:

1. Total term work should include minimum Seven drawing sheets and two assignments. At least one design and drawing should be based on each topic from chapter no.2 to chapter 6. At least one of these drawing should be printed by using any Computer aided design software.

TEXT BOOKS/ REFERENCE BOOKS

1. Process equipment design-vessel design by Lloyd E Brownell and Edwin H.Young, John Wiley, New York 1963.
2. Chemical Engineering, volume 6- Design by J.M Coulson, J.F Richardson and R.K. Sinnott, Pergamon press Intrnational Edition 1989.
3. Introduction to chemical equipment design-Mechanical Aspects by B.C.Bhattacharya, CBS Publications.
4. Process Equipment Design by M.V Joshi, Macmillan India.
5. Pressure Vessel Hand book by Eugene F.Megyesy, Pressure vessel company USA.
6. Design of machine elements by V.B Bhandari, McGraw Hill.
7. Appropriate ISI Specifications and codes for unfired pressure vessels, viz.IS:2825, IS:803,IS:1182, IS:4853, IS:3658, IS:3703, IS:3664, IS:4260, IS:4072, IS:5403, IS:4049, IS:4864, IS:4870, IS:3133, IS:1239, IS:6392, IS:6418,IS:2062, IS:1730, IS800, IS:808, IS:1972, IS:3132, IS:1363, IS:2585,IS:3138, IS:2693, IS:3653,IS:3503, IS:5428.
8. ASME CODE division VIII Section 1&2.
9. Equipment Design Handbook for refineries and chemical plant vol.1&2 by Evans F.L.,Gulf Publishing 1980.
10. Structural analysis and design of equipment by Jawad M.H, Farr J.R,John Wiley 1984.
11. Mixing theories and practices Uhl V.W.and Grey J.B. Academic press New York 1967.
12. AutoDesk 'Manual &Guide on AutoCAD 2000& Mechanical Desktop / Inventor.
13. ISO-9000 series of quality standards.

14. T.E. CHEMICAL (SEM-V)

Class: TE. Chemical Engineering		Semester: V	
5.4 **Solid Fluid Mechanical Operations**			
Periods Per Week (60 Min)	Lectures	04	
	Practical's	02	
	Tutorials	---	
		Hours	Marks
Evaluation System	Theory Examination	03	100
	Practical with Oral Examination	-----	25
	Term Work	----	25
	Total	---	**150**

Detailed Syllabus

5.4.1	Module 1	
	1.1 Introduction: Scope and application of Solid Fluid Operation	01
	1.2 Particulate System and Characterization Introduction to sub micron to mm range. Particle size, measurement methods, shape factor and its measurement, application, particle size distribution, their measurement and representations, by cumulative and differential analysis.	03
5.4.2	Module 2	
	2.1 Size reduction of solids Characterization of comminuted solids. Criteria for commination. Energy and power requirements in combination (crushing laws), size reduction equipments and operations of the equipments (major equipments)	04
	2.2 Screening Efficiency of the screens, ideal and actual screens, screening Equipments, capacity and effectiveness of screens	03
5.4.3	Module 3	
	3.1 Storage and handling of bulk solids Relevant properties of particulate masses such as Angle of repose/ internal friction etc. Vertical / lateral pressure calculations. Storage in bins and hoppers. Flow from bins and hopper. Equipments for solids conveying-conveyors, elevators and feeders.	03
	3.2 Pneumatic and Hydraulic conveying principles, equipments for vertical/horizontal transport (No Numerical) .	02

3.4.4	Module 4	
	Solid liquid separation **4.1** Sedimentation Principles (gravity). Batch sedimentation phenomena of fine and coarse solids, methods to find out the area of thickener and the total depth. Equipment for gravity thickening.	03
	4.2 Centrifugal Sedimentation principles, sigma theory, equipments for centrifugal sedimentation.	03
	4.3 Flocculation-Electrical phenomena at interfaces, interactions between particles, coagulation phenomena, coagulation kinetics, effect of flocculation on sedimentation. Froth flotation, principle equipments.	02
	4.4 Jigging, Tabling, Scrubbing etc	01
3.4.5	**Module 5**	
	5.1 Filtration, Filtration Theory and principles (batch Filtration) constant rate, Constant pressure filtration, effect of cake compressibility, Filtration cycles, filtration equipments (batch and continuous types of filtration and theory equipment)	07
	5.2 Hydrocyclone construction / sizing / operation principles, introduction to microfiltration.	01
3.4.6	**Module 6**	
	6.1 Gas solid separation (Gas cleaning) Solid separation, construction/ operation/ selection / specification of cyclone separators / its design variations, fabric filters, Dust collectors, Electrostatic precipitator.	03
	6.2 Size enlargement Mechanics of Agglomeration / construction / operation / selection / specification of some equipment. Equipment like pressure compaction, pan granulators, Prilling, Drum granulators etc. (No Numericals)	02
	6.3 Mixing of solids -solid mixing equipments construction Oeration selection for free flowing solids and for cohesive solids	02

Theory Examination: 15

1. Question paper will comprise of 7 questions, each of 20 marks.
2. Only 5 questions need to be solved.
3. Question 1 will be compulsory and it will be based on entire syllabus.
4. Remaining questions will be mixed in nature. (for example if Q2 has part (a) from module 3 then part (b) will be from any module other than module 3.)
5. In question paper, weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

TERM WORK:

A minimum of four assignments should be given at regular intervals.

The following parameters should be considered for laboratory performance evaluation. **a.** punctuality **b.** diligence. **c.** contents of journal (originality of discussions)

1. Point nos.1 and 2 above should account for 15 marks (out of 25 marks) for term work
2. Average of minimum of two tests should account for 10 marks (out of 25 marks) for term work
3. Assignments on the following topics (Computer-based assignment on any one of the topics); **a.** size reduction **b.** screening **c.** sedimentation and centrifugal sedimentation & **d.** filtration
4. Each and every experiment should conclusively demonstrate / verify the theory. Experimental results should corroborate with theoretical / estimated / reported values. The students should explain variations between observed and expected results based on technical grounds and systematic error evaluation. Each experimental report should contain a discussion of the results obtained.
5. Any ten (10) of the following laboratory experiments in the solid fluid mechanical operations be perform as term work.
   I. Size reduction by jaw crusher.
   II. Size reduction by hammer mill.
   III. Size reduction by ball mill.
   IV. Filtration in plate and frame filter press.
   V. Vacuum filtration.
   VI. Batch sedimentation.
   VII. Sigma mixer.
   VIII. Sieving and PSD.
   IX. Elutriations and PSD.
   X. Effectiveness of screens / Vibrating screens.
   XI. Demonstration Experiment: Gas- Solid separation by cyclone separator.

TEXT BOOKS:

16

1) MaCabe W.L., Smith J C., Harriot P.P Unit Operations of Chemical Engg 5th Edition. McGraw Hill International 1993
2) Coulson J M., Richardson J E., Backhurst I R., Harker J H., Coulson and Richardson's Chemical Engg. 4th Edition Vol 1,2., Pergamon press, 1990
3) Coulson J M., Richardson J F., Sinnot R K., Coulson and Richardson's Chemical Engg 2nd Edition. Vol 6, Pergamon press, 1993

REFERENCE BOOKS:

1) Perry R. II, Green D., Perry's Chemical Engg Hand Book McGraw Hill, 6th Edition 1984.
2) Walas S. M., Chemical process Equipment, Selection and Design, Butterworth Henemann 1990.
3) King C. J. Seperation processes, Tata Mcgraw Hill. 1974.
4) Foust A. S et al., principles of unit operations 2nd edition, John wiley & Sons, 1980.
5) Badger and Banchero, introduction to chemical engg.

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T.E. CHEMICAL (SEM-V)

Class: TE. Chemical Engineering		Semester: V	
5.5 **Mass Transfer Operations-I**			
Periods Per Week (60 Min)	Lectures	04	
	Practical's	02	
	Tutorials	--	
		Hours	Marks
Evaluation System	Theory Examination	03	100
	Practical with Oral Examination	-----	25
	Term Work	----	25
	Total	---	**150**

Sr. No.	Detailed Syllabus	Hours
5.5.1	Module I	
	1.1 Diffusion in Liquids and gasses : Fick's Law of Diffusion, Definition of various fluxes and relation between them 1.2 Diffusivity – definitions, and method of estimations, binary and multi component situations 1.3 Special case of binary mass transfer – equimolar counter diffusion, and diffusion of one component through non diffusing second component, numerical examples. 1.4 Diffusion in solids, types of solid diffusion , numerical examples.	09
5.5..2	Module 2	
	2.1 Mass transfer coefficient definition and evaluation in Laminar flow Turbulent flow 2.2 Theories of evaluation of mass transfer coefficient 2.3 Evaluation of mass transfer coefficient through analogy with heat and momentum transfer , numerical examples. Effect of mass transfer on heat transfer	05
5.5.3	Module 03	
	3.1 Inter phase mass transfer : Equilibrium 3.2 Mass transfer coefficient in individual phases 3.3 Overall mass transfer coefficient and relation between local and overall coefficient. Concept of phase with major resistance to mass transfer. numerical examples. 3.4 Methods of contacting phases: stage wise and continuous contact. Co-current, counter-current and cross current operations. Example of operation. 3.5 Equilibrium stage definition and concept, steady state, equilibrium stage operation : material balance, concept of	09

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	operating line and equilibrium line, theoretical stage, point and sage efficiencies, overall efficiencies. Continuous contacting , concept of NTU, HTU, HETP etc.	
5.5.4	Module 04	
	4.1 Equipment for gas liquid contacting : *Construction, sizing and operation* 4.2 (Mass transfer operations, efficiencies, general characteristic, dimensions and operating characteristic, numerical examples.) 4.3 Gas dispersed gas continuous – sparged vessels, tray tower and mechanical agitated vessels. 4.4 Liquid dispersed in continuous gas phase –venturi scrubber, spray chambers, wetted wall column etc. 4.5 Packed towers. Comparison of stage wise and continuous contacting equipment.	05
5.5.5	Module 05	
	5.1 Gas Absorption 5.2 Equilibrium (solubility of gasses in liquids), effect of temperature and pressure, reference substance plots, ideal and non-ideal solution, Heat of solution, factor affecting choice of solvent. 5.3 Single component isothermal gas absorption : stage wise and continuous contact. Co-current, counter current and cross current operations, concentrated and dilute solutions, Relation between overall and individual phase HTUs, numerical examples. 5.4 Single component adiabatic gas absorption: Equations and method of calculations (numerical examples not included) 5.5 Multi component isothermal gas absorption : Equation and method of calculation (numerical examples not included) 5.6 Absorption with chemical reaction: Examples with mass transfer controlling, equation and numerical examples Equipment description	10
5.5.6	Module 06	
	6.1 Humidification and de-humidification operation : 6.2 Vapor liquid equilibrium and enthalpy, numerical examples 6.3 Vapor-gas mixtures : Definitions, Saturated and unsaturated mixture characteristic, Review of Psycrometric charts, Adiabatic saturation and wet bulb temperature, Lewis Relation, Numerical Examples. 6.4 Adiabatic Operation : (Air water systems) Water coolers, cooling towers, design of cooling towers, Numerical Examples.	12

	6.5 Non-adiabatic operations : Evaporative cooling, Numerical Examples. Equipment description 6.6 Drying : 6.7 Moisture Definitions and equilibrium 6.8 Drying operation – batch and continuous 6.9 Batch Drying – Mechanism, rate of drying curve, equipment and operation, Numerical Examples. 6.10 Continuous drying – equipment and operation Design of rotary drum dryer, Numerical Examples.	

Theory Examination:

1. Question paper will comprise of 7 questions, each of 20 marks.
2. Only 5 questions need to be solved.
3. Question 1 will be compulsory and it will be based on entire syllabus.
4. Remaining questions will be mixed in nature. (for example if Q2 has part (a) from module 3 then part (b) will be from any module other than module 3.)
5. In question paper, weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

TERM WORK

1) A minimum of four assignments should be given at regular intervals.
2) The following parameters should be considered for laboratories performance evaluation
   a) Punctuality b) Diligence c) Content of Journal (Originality of Discussion)
3) Point Nos. 1 and 2 above should be account for 15 Marks (Out of 25 Marks) for term work.
4) Average of two minimum two test should account for 10 marks (Out of 25 Marks) for term work.
5) Each and every experiment should conclusively demonstrate / verify the theory. Experimental result should corroborate with theoretical / reported / estimated values. The student should explain the variations between observed and expected results based on technical grounds and systematic error evaluation. Each experimental report should content a discussion of the result obtained..
6) A minimum of ten experiments should performed. A suggested list is given below
   1) Measurement of diffusion coefficient
   2) Measurement of mass transfer coefficient in a gas-liquid systems
   3) Measurement of mass transfer coefficient in a liquid-liquid systems
   4) Measurement of mass transfer coefficient in a solid-liquid systems
   5) Absorption in packed column
   6) Absorption in sparged column
   7) Absorption in spray column
   8) Cooling tower
   9) Air cooler
   10) Batch Drying : rate of drying curve
   11) Vacuum drying
   12) Hydrodynamics of gas-liquid contacting in packed column.

TEXT BOOKS:

20

1) Treybal R. E., Mass Transfer Operations. 3rd Edition, McGraw Hill New York, 1980
2) McCabe W. L. and Smith J. C., Unit operation in chemical Engineering, 5 th Edition, McGrall Hill, New York, 1993
3) Geankoplis C. J., Transport Processes and Unit Operations, Prentice Hall, New Delhi, 1997
4) Coulson J. M., Richardson J. F., Backhurst J. R. and Harker J. H., Coulson and Richardson Chemical Engineering, Vol 1, Butterworth Heinman, New- Delhi, 2000
5) Coulson J. M., Richardson J. F., Backhurst J. R. and Harker J. H., Coulson and Richardson Chemical Engineering, Vol 2, Ashian book Ptv. Ltd., New- Delhi, 2000
6) R. K. Sinnot, (Ed) Coulson and Richardson Chemical Engineering, Vol 6, Butterworth Heinman, New- Delhi, 2000

Reference Books :

1) Cussler E. L., Diffusion: Mass Transfer in Fluid Systems, 2 nd Edition, Cambridge University Press, 1998
2) Perry J. H. and Chilton, Perry's Chemical Engineering Hand Book, 6th McGrall Hill, 1984
3) Sherwood T. K., Pigford R. L., and Wilke C. R. Mass Transfer, McGrall Hill, 1975
4) Yang R. T., Gas Separation By Absorption Process , Butterworth, London,1987
5) Schweitze P. A. (Ed), Hadbook for Separation Technique Foe Chemical Engineer. McGrall Hill, New York, 1998
6) Walas S. M., Chemical Process Equipment : Selection and Design, Butteworth, London, 1989
7) Mujumdar A. S. (Ed) Handbook of industrial Drying, Marcel-Decker, London,1987
8) Bird R. B. and Stewart W. E. and Lightfoot E. N., Transport Phenomena, Wiley,New-York,1960

T.E. CHEMICAL (SEM-V)

Class: TE. Chemical Engineering		Semester: V	
5.6 **Chemical Engineering Economics**			
Periods Per Week (60 Min)	Lectures	04	
	Practical's	00	
	Tutorials	--	
		Hours	Marks
Evaluation System	Theory Examination	03	100
	Practical with Oral Examination	-----	---
	Term Work	----	---
	Total	---	**100**

Sr. No.	Detailed Syllabus	Hours
5.6.1	Module 1	
	Basic principals of economics • Importance of Economics to Chemical Engineer • Concepts of needs , cost and price etc • Demand supply analysis • Economics of production • Markets and pricing • Introduction to economics of growth	04
5.6.2	Module 2	
	Interest and Investment Costs • Types of Interest Simple Interest, Compound Interest • Nominal and effective interest rates, continuous interest • Present Worth and Discount • Annuities • Perpetuities and Capitalized Cost • Cash Flow in Chemical Project • Taxes and Insurance	09
5.6.3	Module 3	
	Cost Estimation ▪ Cash flow for Industrial Operation, Cumulative Cash Position ▪ Types of capital cost estimates. ▪ Factors affecting investment and production cost. ▪ Constituents , capital – fixed , working ▪ Estimation of capital investment and cost of product ▪ Cost Indices ▪ Break Even Analysis	08

5.6.4	Module 4	
	Depreciation • Introduction to concepts of value, depletion, cost maintenance and repairs, service life, salvage value, scrap value, present value, book value, market value, replacement value • Methods for determining depreciation Straight-Line method Declining balance method Sum of years digits method Sinking Fund method Accelerated Cost Recovery system	07
5.6.5	Module 5	
	Profitability, Alternative Investments and Replacements Mathematical methods for Profitability evaluation • Rate of return method • Discounted Cash Flow • Net Present Worth • Capitalized Cost • Pay Out Period Alternative Investments with small investment increments Replacements	09
5.6.6	Module 6	
	Cost Accounting • Concepts and definitions of financial ratios • Balance sheets , profit and loss accounting • Cost accounting and reporting	06

Theory Examination:

1. Question paper will comprise of 7 questions, each of 20 marks.
2. Only 5 questions need to be solved.
3. Question 1 will be compulsory and it will be based on entire syllabus.
4. Remaining questions will be mixed in nature. (for example if Q2 has part (a) from module 3 then part (b) will be from any module other than module 3.)
5. In question paper, weightage of each module will be proportional to number of respective lecture hours as mentioned in the syllabus.

Text Books

1. Peters , M. S. and Timmerhaus , K. D. ," Plant design and economics for chimical engineers " ,4th ed. ,Mcgraw Hill , New York , 1995
2. Kharbanda , O. P. and Stallworthy , E. A. " Capital cost estimating for process industries , Butterworths, Londen , 1988
3. Humphreys , K. K. " Jellens cost and optimization engineering ", 3rd ed. ,McGraw Hill, 1991
4. K.K Dewett and Adarsh Chand, " Modern Economic Theory", 21st Edition, S Chand and Company
5. O.P Khanna, "Industrial Engineering and Management" Dhantpat Rai Publications (P) Ltd., 1992