SCHEME AND SYLLABUS

B.TECH.-III (CHEMICAL) 5th SEMESTER SCHEME FOR TEACHING AND EXAMINATION

CS: Core Subject **EIS: Elective Interdisciplinary Subject**

ES: Elective Subject (from Department) **IS: Interdisciplinary Subject**

Sr. No.	Course	Code	Credits	Teaching Scheme Hours per Week			Examination Scheme						Total Marks
							Theory				Practicals		
				L	Tu	Pr	Hr	Sessional	Tu	End Sem	Sessional	End Sem	
1	Chemical Engineering Thermodynamics-I (CS-1)	CH 301	4	3	1	0	2	50	25	50	---	---	125
2	Heat Transfer Operations (CS-2)	CH 303	5	3	1	2	2	50	25	50	20	30	175
3	Mass Transfer Operations-I (CS-3)	CH 305	5	3	1	2	2	50	25	50	20	30	175
4	Mechanical Operations (CS-4)	CH 307	5	3	1	2	2	50	25	50	20	30	175
5	EIS-1*		3	3	0	0	2	50	---	50	---	---	100
	TOTAL		22	15	4	6		250	100	250	60	90	750

Total contact hours per week = 25 **Total Credit = 22** **Total marks = 750**

B.TECH.-III (CHEMICAL) 6th SEMESTER SCHEME FOR TEACHING AND EXAMINATION

Sr. No.	Course	Code	Credits	Teaching Scheme Hours per Week			Examination Scheme						Total Marks
							Theory				Practicals		
				L	Tu	Pr	Hr	Sessional	Tu	End Sem	Sessional	End Sem	
1	Chemical Engineering Thermodynamics-II (CS-1)	CH 302	4	3	1	0	2	50	25	50	---	---	125
2	Chemical Reaction Engineering -I (CS-2)	CH 304	5	3	1	2	2	50	25	50	20	30	175
3	Fluid Flow Operations (CS-3)	CH 306	5	3	1	2	2	50	25	50	20	30	175
4	Mass Transfer Operations-II (CS-4)	CH 308	5	3	1	2	2	50	25	50	20	30	175
5	EIS-2*		3	3	0	0	2	50	---	50	---	---	100
	TOTAL		22	15	4	6		250	100	250	60	90	750

Total contact hours per week = 25 **Total Credit = 22** **Total marks = 750**

*** Students have to opt for one subject from each Elective Interdisciplinary Subject Group-1 & 2 as listed below:**

EIS: Elective Interdisciplinary Subjects (Group-1)#	EIS: Elective Interdisciplinary Subjects (Group-2)#
CH 309: Bioprocess Engineering CH 311: Energy Technology CH 313: Fertilizer Technology CH 315: Fuels and Combustion CH 317: Polymer Science and Engineering	CH 312: Bioseparations CH 314: Cleaner Technologies in Chemical Process Industries CH 316: Introduction to Industrial Biotechnology CH 318 Petrochemical Technology CH 322: Petroleum Refinery Engineering

B.Tech. III (CH), Semester-V	L	T	P	C
CH 301: CHEMICAL ENGINEERING THERMODYNAMICS - I	3	1	0	4

- **INTRODUCTION (6 Hours)**

Conservation of energy and first law of thermodynamics, application to steady state flow process, enthalpy, internal energy, equilibrium state, phase rule, reversible and irreversible processes, heat capacity specific heat.

- **PROPERTIES OF PURE SUBSTANCES (8 Hours)**

P-V-T behavior, ideal and non-ideal gases, different equations of state for real gases.

- **HEAT EFFECTS (5 Hours)**

Heat capacities of gases as a function of temperature of liquids and solids, heat of vaporization, heat of fusion, heat of sublimation, etc.

- **SECOND AND THIRD LAW OF THERMODYNAMICS (7 Hours)**

Thermodynamic temperature scale, ideal gas temperature scale, concept of entropy, entropy change and irreversibility, third law of thermodynamics.

- **THERMODYNAMIC PROPERTIES OF FLUID (8 Hours)**

Mathematical relation among thermodynamic functions, Mexwell's relations, Interrelation between H, S, U, G, Cp, Cv, properties of single and two phase system. Types of thermodynamic diagrams.

- **THERMODYNAMICS OF FLOW PROCESS (6 Hours)**

Fundamental relation for flow in pipes, maximum velocity in pipe flow, throttling process, flow through nozzles, single stage and multi stage compressors.

- **REFRIGERATION AND LIQUEFACTION: (5 Hours)**

Carnot refrigeration cycle, air refrigeration cycle, absorption refrigeration, heat pump, choice of refrigeration, liquefaction processes.

(Total contact time: 45 hours)

BOOKS RECOMMENDED:

1. Smith J. M., Van Ness H. C., M.M. Abbott, "Introduction to Chemical Engineering Thermodynamics", 6th Ed., McGraw-Hill, New York, 2001
2. Dodge B. F., "Chemical Engineering Thermodynamics", McGraw-Hill Book Co., New York, 1960.
3. Rao Y. V. C., "Chemical Engineering Thermodynamics", Universities Press Limited, Heydrabad, 1997.
4. Kyle, B.G., "Chemical and Process Thermodynamics", 2nd Ed., Prentice-Hall of India, New Delhi,1990.
5. Sandler, S.I., "Chemical and Engineering Thermodynamics", 2nd Ed., Wiley, New York, 1989.

B. Tech. III (CH), Semester – V

L	T	P	C
3	1	2	5

CH 303: HEAT TRANSFER OPERATIONS

- **INTRODUCTION** **(02 Hours)**
  Modes of Heat Transfer: Conduction, Convection and Radiation
- **CONDUCTION** **(05 Hours)**
  Fourier conduction equation, General conduction equation in Cartesian, Cylindrical and Spherical co-ordinates, Steady state and transient conduction equation.
- **FORCED CONVECTION** **(10 Hours)**
  Heat transfer in fluids without phase change, Forced convection, Dimensional analysis, Heat transfer in laminar and turbulent flows inside and outside tubes. Concept of thermal boundary layer, Overall heat transfer coefficient, LMTD, Fouling factors, Transfer units, Flow over flat plates with heat transfer, Empirical correlations.
- **NATURAL CONVECTION** **(04 Hours)**
  Qualitative description of free convection flows, Hear transfer correlations for free convection.
- **BOILING AND CONDENSATION** **(04 Hours)**
  Boiling phenomena: Regimes of boiling etc, Condensation: Film and drop condensation etc.
- **EVAPORATION AND CRYSTALIZATION** **(06 Hours)**
  Single effect and Multi-effect evaporation, Forward and backward feed system.
  Equilibrium in crystallization, operation and equipment.
- **HEAT EXCHANGERS** **(06 Hours)**
  Double pipe heat exchanger and Shell-and-tube heat exchanger, its applications and design
- **RADIATION HEAT TRANSFER** **(04 Hours)**
  Basic concepts of radiation heat transfer, Radiative heat exchange between surfaces, Radiation shield.
- **EXTENDED SURFACES** **(04 Hours)**
  Heat transfer from extended surfaces, fin efficiency

(Total contact time: 45 hours)

PRACTICALS:

1. Experiment on "Heat transfer through composite wall at different temperature"
2. Experiment on "Thermal conductivity of insulating powder (Asbestos powder)
3. Experiment on "Heat transfer in double pipe heat exchanger in laminar flow"
4. Experiment on "Heat transfer in turbulent flow"
5. Experiment on "Heat transfer by forced convection"
6. Experiment on "Heat transfer coefficient in natural convection"
7. Experiment on "Extended surface heat transfer"
8. Experiment on "Shell and tube heat exchanger"
9. Experiment on "Heat transfer by radiation: Stefan-Boltzmann Law"

BOOKS RECOMMENDED:

1. McCabe W.L., Smith J.C., Harrott P., "Unit Operations of Chemical Engineering", 6th & 7th Eds. McGraw-Hill, New York, 2001 & 2005.
2. Kern D. Q., "Process Heat Transfer", McGraw-Hill, New York, 1950.
3. Hollman J. P., "Heat Transfer – Basic approach", McGraw-Hill, New York, 1985.
4. Gebhart B. U., "Heat Transfer", Tata McGraw-Hill, New York, 1961.
5. Coulson J.M., Richardson J.F., Backhurst J. R., Harker J.H. "Chemical Engineering" Vol. 1. 6th Ed. Elservier, New Delhi, 2004.

B. Tech. III (CH), Semester-V	L	T	P	C
CH 305: MASS TRANSFER OPERATIONS-I	**3**	**1**	**2**	**5**

- **INTRODUCTION** **(02 Hours)**
  Introduction to Mass Transfer Operation: classification & method.
- **DIFFUSION AND MASS TRANSFER** **(08 Hours)**
  Molecular diffusion in fluids, steady state diffusion
  (both gases & liquids), diffusivity of liquids & gases.
- **MASS TRANFER COEFFICIENTS** **(03 Hours)**
  Mass Transfer co-efficient in laminar & turbulent flow,
  Mass, Heat and Momentum transfer analogies
- **DIFFUSION IN SOLIDS** **(06 Hours)**
  Introduction to diffusion in solids, Fick's law, types of solid diffusion
- **INTER PHASE MASS TRANSFER** **(04 Hours)**
  Equilibrium, diffusion between phases, material balance, stages
- **DISTILLATION** **(16 Hours)**
  VLE data, flash, differential and continuous distillation,
  McCabe-Thiele and Ponchon-Savarit method, Azeotropic,
  Extractive, Reactive, Molecular and Multicomponent distillation,
  Equipment for gas-liquid operation
- **HUMIDIFICATION** **(06 Hours)**
  Vapor-gas mixtures, vapor-liquid equilibrium,gas-liquid contact operations,
  adiabatic & non-adiabatic operations.

(Total contact time: 45 hours)

PRACTICALS

1. Humidification and dehumidification
2. Mass transfer coefficient
3. Crystallization
4. Azeotropic distillation
5. Diffusion coefficient
6. Latent heat of vaporization
7. Cooling tower
8. Packed distillation

BOOKS RECOMMENDED:

1. Treybal R.E., "Mass-Transfer Operations", 3rd Ed., McGraw-Hill, New York, 1981.
2. McCabe W.L, Smith J.C., Harriott P., "Unit Operations in Chemical Engineering", 6th & 7th Eds., McGraw-Hill, New York,2001 & 2005.
3. Coulson J.M., Richardson J.F., Backhurst J. R., Harker J.H. "Chemical Engineering" Vol. 1. 6th Ed. Elservier, New Delhi, 2004.
4. Sherwood, T.K., Pigford, R.L., Wilke, C.R., "Mass Transfer", McGraw-Hill, New York, 1976.
5. Cussler E.L.,"Diffusion: Mass Transfer in Fluid Systems", 2nd Ed., Cambridge University Press, Cambridge, 1997.

B. Tech. III (CH), Semester – V	L	T	P	C
CH 307: MECHANICAL OPERATIONS	**3**	**1**	**2**	**5**

- **INTRODUCTION** **(03 Hours)**
  Solids, Storage, Transportation and Handling of Solis, Liquid and Gases, characteristics of solid particles

- **SIZE REDUCTION** **(05 Hours)**
  Size reduction and enlargement, crushers, grinders, disintegrates for coarse & intermediate & fine grinding, energy and power requirements, law of crushers, work index, etc.

- **SCREENING AND OTHER SEPARATION METHODS** **(10 Hours)**
  Screening and other separation methods: screen analysis, estimation of particle size, surface area and particle population based on screen analysis, ideal and actual screens, principles of elutriation, flotation, jigging, electrostatics, and magnetic separation processes, Cyclones, Hydroclones, Centrifugal Decanter.

- **SEDIMENTATION** **(05 Hours)**
  Sedimentation, Settling velocity, flocculation, Thickener, Sedimentation zones.

- **FILTRATION** **(10 Hours)**
  Filtration, filter media, filter aids, batch & cont. filtration, filtration equipment, filter press, leaf, cartridge, vacuum filter, rotary drum filters.

- **MIXING AND AGITATION** **(09 Hours)**
  Equipments for agitation, agitation of liquids, types of impellers, power consumption in agitated vessels etc.

- **CONVEYERS** **(03Hours)**
  Mechanical and Pneumatic conveying, elevators, Bins, silos etc.

(Total contact time: 45 hours)

PRACTICALS:

1. Determination of particle size by sieve analysis.
2. Determination of the optimum speed and critical speed of a ball mill.
3. Measurement of different bulk properties of powder samples.
4. To study powder compaction behavior using different powder compaction models.
5. Study of particle size reduction by Roll crusher and Jaw crusher
6. Characterization of powder flowability by Angle of Repose.
7. Obtaining the collection efficiency of cyclone
8. Obtaining settling rates of slurry as function of solid concentration
9. Study of pressure drop as function of superficial velocity
10. To characterize particle size and shape using image processing by ImageJ software**.**

BOOKS RECOMMENDED:

1. McCabe W.L., Smith J.C., Harriott P., 'Unit Operations of Chemical Engineering", 6^{th} & 7^{th} Eds., McGraw-Hill, New York, 2001 & 2005.
2. Foust A.S., Wenzel L.A., Clump C.W., Maus L., Anderson L.B. "Principles of Unit Operations", John Wiley & Sons, New York, 1980.
3. Brown G.G., "Unit Operations", John Wiley & Sons, New York, 1953.
4. Badger W.L., Banchero J.T., "Introduction to Chemical Engineering", McGraw Hill, New York, 1997.
5. Coulson J.M., Richardson J.F., "Chemical Engineering", Vol. 2, 5^{th} Ed., Elservier, New Delhi, 2002.

B.Tech. III (CH), Semester-VI	L	T	P	C
CH 302: CHEMICAL ENGINEERING THERMODYNAMICS - II	**3**	**1**	**0**	**4**

- **THERMODYNAMIC PROPERTIES OF FLUIDS (12 Hours)**
  Partial molar properties, chemical potential, non-ideal solution, fugacity, and fugacity co- efficient, for pure components and for mixture of gases, and for liquids. Lewis randall rule, Henry's law, excess property, activity and activity co-efficient.

- **PHASE EQUILIBRIUM (15 Hours)**
  Phase rule, Duhem theory, miscible system, immiscible system, partially immiscible system, testing of vapor-liquid equilibrium data, Gibbs-Duhem equation, Van Laar equation. Margules equation, Redlich-Kister equation, P-X-Y, T-X-Y, & X-Y Diagram, vapor-liquid equilibrium of ideal and non-ideal solution, Roult's law & Henry's law.

- **CHEMICAL EQUILIBRIUM (10 Hours)**
  Criteria, equilibrium conversion (X), constant (K), effect of Temp. & Pressure on K, evaluation of K, evaluation of equilibrium conversion for gas phase reaction.

- **INTRODUCTION TO STATISTICAL THERMODYNAMICS (8Hours)**
  Stefen-Boltzman, Bose-Einstein and Fermi-Dirac distributions, corrected boltzman statistics, partition function etc.

(Total contact time: 45 hours)

BOOKS RECOMMENDED:

1. Smith J. M. Van Ness H. C., Abbott M.M., "Introduction to Chemical Engineering Thermodynamics", 6th & 7th Eds., McGraw-Hill, New York, 2001 & 2005.
2. Dodge B. F., "Chemical Engineering Thermodynamics", McGraw-Hill, New York, 1960.
3. Rao Y. V. C., "Chemical Engineering Thermodynamics", Universities Press Limited, Heydrabad, 1997.
4. Sonntag R.E., Van Wylen G.J., "Fundamentals of Statistical Thermodynamics", John Wiley & Sons, Singapore, 1991.
5. Sandler, S.I., "Chemical and Engineering Thermodynamics", 2nd Ed., Wiley, New York, 1989.

B. Tech. III (CH), Semester-VI	L	T	P	C
CH 304: CHEMICAL REACTION ENGINEERING - I	**3**	**1**	**2**	**5**

- **INTRODUCTION** **(01 Hour)**
  Chemical kinetics, Classification of reactions, Variables affecting the rate of reaction, Reaction rate
- **KINETICS OF HOMOGENEOUS REACTIONS** **(06 Hours)**
  Concentration dependent term and temperature dependent terms of rate equation, Single and multiple reactions, Elementary and non-elementary reactions, Molecularity and order of reaction, Rate constant, Representation of reaction rate, Kinetic models, Temperature dependency from Arrhenius' law, thermodynamics, various theories, Activation energy, Searching for the reaction mechanism
- **INTERPRETATION OF BATCH REACTOR DATA** **(08 Hours)**
  Constant volume batch reactor, Variable volume batch reactor, Integral method and differential method of analysis of kinetic data, Temperature and reaction rate
- **INTRODUCTION TO REACTOR DESIGN** **(03 Hours)**
  Types of reactors, PFR, CSTR etc., Material & energy balances single ideal reactor, Space-time and space-velocity, Holding time, Introduction of non-ideal flow
- **DESIGN FOR SINGLE REACTIONS** **(08 Hours)**
  Size comparison of single reactors, General graphical comparison, Multiple reactor system, Recycle reactor, Autocatalytic reactions
- **DESIGN FOR MULTIPLE REACTIONS SYSTEMS** **(08 Hours)**
  Reaction in parallel, Reaction in series, Series-parallel reaction and applications
- **TEMPERATURE & PRESSURE EFFECTS** **(04 Hours)**
  Single & multiple reactions, Heats of reaction from thermodynamics, Product distribution
- **INDUSTRIAL APPLICATIONS** **(04 Hours)**
  Types of reactors used in industries, Advanced chemical reactors.
- **INTRODUCTION TO BIOCHEMICAL REACTION ENGINEERING** **(03 Hours)**
  Types of bio-reactors, Design, scale-up, operation and control of bio-reactors, Kinetics of biochemical reactions

(Total contact time: 45 hours)

PRACTICALS:

1. Integral method of analysis of kinetic data
2. Differential method of analysis of kinetic data
3. Activation energy and frequency factor
4. Half-life method
5. Pseudo first order reaction
6. Study of kinetics of the reaction in presence of DC current
7. Study of membrane reactor
8. Study of spiral coiled reactor
9. Study of annulus flow reactor
10. Study of specific reaction/reactor system

BOOKS RECOMMENDED:

1. Levenspiel O., "Chemical Reaction Engineering", 3rd Ed., John Wiley & Sons, Singapore, 1998.
2. Fogler H.S., "Elements of Chemical Reaction Engineering", 4th Ed., Prentice-Hall, NJ, 2006.
3. Smith J. M., "Chemical Engineering Kinetics", 3rd Ed., McGraw-Hill, New York, 1981.
4. Froment G.F., Bischoff K.B., "Chemical Reactor Analysis and Design", 2nd Ed., John Wiley & Sons, Singapore, 1990.
5. Inamdar S.T.A., "Biochemical Engineering – Principles and Concepts", Prentice-Hall of India, New Delhi, 2007.
6. Shuler M.L., Kargi F., "Bioprocess Engineering – Basic Concepts", 2nd Ed., Prentice-Hall of India, New Delhi, 2006.

B. Tech. III (CH), Semester –VI	L	T	P	C
CH 306: FLUID FLOW OPERATIONS	**3**	**1**	**2**	**5**

- **INTRODUCTION** **(4 hours)**
  Definitions of Unit operations, Basic concepts of fluids and its application area, Properties of fluids, Unit systems, Standards, Conversion on units, Units and equations, Dimension analysis, Dimension and units, Dimensional homogeneity, Dimensionless equations, Buckingham π theorem, Common π groups, examples.

- **FLUID STATIC & ITS APPLICATIONS** **(3 hours)**
  Nature of fluids: Incompressible and compressible fluids, Pressure concepts, Hydrostatic equilibrium in gravitational and centrifugal field, Manometers, Inclined manometer, Continuous gravity and centrifugal decanter.

- **FLUID FLOW PHENOMENA** **(4 hours)**
  Types of flow, Potential flow, One dimensional flow, Laminar flow, Reynolds number, Newtonian and non-Newtonian fluids, Velocity gradient and Rate of shear, Viscosity of gases and liquids, Turbulent flow, Nature of turbulence, Eddy viscosity, Eddy diffusivity of momentum, Flow in boundary layers, Laminar and turbulent flow in boundary layers, Boundary layer formation in straight tube and flat plates, Boundary layer thickness, Boundary layer separation and wake formation.

- **BASIC EQUATIONS OF FLUID FLOW** **(6 hours)**
  Stream line and stream tubes, Average velocity, Mass velocity, Momentum balance, Bernoulli's equation without friction, Correction of Bernoulli's equation for fluid friction, Pump work in Bernoulli's equation.

- **FLOW OF INCOMPRESSIBLE FLOW AND ITS APPLICATIONS IN CONDUITS AND THIN LAYERS** **(6 hours)**
  Flow of incompressible fluids in pipes, Friction factor, Laminar flow of Newtonian and non-Newtonian fluids, Turbulent flow in pipes and closed channels, Effect of roughness, Friction factor chart, Drag reduction in turbulent flow Friction factor in flow through channels of noncircular cross section, Friction from changes in velocity or direction, Effect of fittings and valves, Practical use of velocity heads in design, Minimization expansion and contraction losses.

- **FLOW OF COMPRESSIBLE FLUIDS AND ITS APPLICATIONS** **(4 hours)**
  Continuity equations, Velocity of sound, Stagnation temperature, Processes of compressible flow.

- **FLUID FLOW MEASUREMENTS** **(8 hours)**
  Fluid flow measurement: venture meter, Orifice meter, Rotameter, Pitot tubes, etc.

- **APPLICATIONS OF FLUID MECHANICS** **(10 hours)**
  Transportation and metering of fluids: Pipe, fitting and valves, pumps, compressor, blowers and fans, Flow past immersed bodies: Drag, Drag coefficients, Flow through beds of solids, Particle motion, Terminal velocity, Hindered settling, Settling and rise of bubbles and drops, Fluidization, Introduction to computational fluid dynamics (CFD).

(Total contact time: 45 hours)

PRACTICALS

1. Experiment on viscosity by Stokes' law
2. Experiment on Reynolds number
3. Experiment on friction in circular pipe
4. Experiment on friction in annulus
5. Experiment on venturimeter
6. Experiment on orifice meter
7. Experiment on characteristics of centrifugal pump
8. Experiment on equivalent length of pipe fittings

BOOKS RECOMMENDED

1. McCabe W.L., Smith J.C., Harriott P., "Unit Operations of Chemical Engineering", 6th & 7th Eds., McGraw-Hill, New York, 2001 & 2005.
2. Coulson & Richardson's Chemical Engineering, Vol. 2, 5th Ed., Elesevier, New Delhi, 2005.
3. Coulson & Richardson's Chemical Engineering, Vol. 4, 2nd Ed., Elesevier, New Delhi, 2001.
4. Coulson & Richardson's Chemical Engineering, Vol. 6, 4th Ed., Elesevier, New Delhi, 2006.
5. de Nevers N., "Fluid Mechanics for Chemical Engineers", 2nd Ed., McGraw-Hill, New York, 1991.

B. Tech. III (CH), Semester-VI	L	T	P	C
CH 308: MASS TRANSFER OPERATIONS-II	**3**	**1**	**2**	**5**

- **ABSORPTION (10 Hours)**
  Equilibrium, material balance for single component transfer, multi-stage & packed tower operation, multicomponent system, non-isothermal operation, absorption with chemical reaction

- **LIQUID EXTRACTION (08 Hours)**
  Liquid equilibria, stage wise extraction, stage type extractor, differential extractor

- **ADSORPTION AND ION-EXCHANGE (06 Hours)**
  Adsorption equilibria, stage wise and continuous operations

- **DRYING (06 Hours)**
  Equilibrium, batch drying, mechanism, continuous

- **LEACHING (04 Hours)**
  Steady state & unsteady state operations**,** methods of calculation

- **CRYSTALLIZATION (03 Hours)**
  Equilibrium, operations and equipment

- **INTRODUCTION TO RECENT SEPARATION TECHNIQUE (08 Hours)**
  Ultrafiltration, reverse osmosis, nanofiltration, liquid membrane

(Total contact time: 45 hours)

PRACTICALS

1. Leaching
2. Liquid-liquid extraction
3. Freundlich isotherm
4. Ternary diagram
5. Drying
6. Fluidization apparatus
7. Cooling tower
8. Fluid bed dryer
9. Evaporator

BOOKS RECOMMENDED:

1. Treybal R.E., "Mass-Transfer Operations", 3rd Ed., McGraw-Hill, Singapore, 1981.
2. McCabe W.L, Smith J.C., Harriott P., "Unit Operations in Chemical Engineering", 6th &7th Eds., McGraw-Hill, New York, 2001 & 2005.
3. Coulson J.M., Richardson J.F., Backhurst J. R., Harker J.H. "Coulson & Richardson's Chemical Engineering", Vol. 1, 6th Ed., Elservier, New Delhi, 2004.
4. Chopey N.P., "Handbook of Chemical Engineering Calculations", 3rd Ed., McGraw-Hill, New York, 2004.
5. Suryanarayana A., "Mass Transfer Operations", New Age International, New Delhi, 2002.