UNIVERSITY OF KERALA

B. TECH. DEGREE COURSE

(2013 SCHEME)

SYLLABUS FOR

VI SEMESTER

CHEMICAL ENGINEERING

SCHEME -2013

VI SEMESTER
CHEMICAL ENGINEERING (H)

Course No	Name of subject	Credits	Weekly load, hours			C A Marks	Exam Duration Hrs	U E Max Marks	Total Marks
			L	T	D/ P				
13.601	Mass Transfer Operations I (H)	4	3	1	-	50	3	100	150
13.602	Chemical Reaction Engineering II (H)	4	3	1	-	50	3	100	150
13.603	Heat Transfer Operation II (H)	4	2	2	-	50	3	100	150
13.604	Process Dynamics and Control (H)	4	2	2	-	50	3	100	150
13.605	Numerical Methods for Process Engineers (H)	4	2	2	-	50	3	100	150
13.606	Elective II	3	2	1	-	50	3	100	150
13.607	Chemical Reaction Engineering Lab (H)	3	-	-	3	50	3	100	150
13.608	Heat Transfer Operations Lab (H)	3	-	-	3	50	3	100	150
	Total	**29**	**14**	**9**	**6**	**400**		**800**	**1200**

13. 606 Elective I

13.606.1	Bioprocess Technology and Fermentation Engineering (H)
13.606.2	Electrochemical Technology (H)
13.606.3	Solar Energy Engineering (H)
13.606.4	Project Engineering (H)
13.606.5	Operational Research (H)
13.606.6	Production of Particulate Systems (H)

13.601 MASS TRANSFER OPERATIONS I (H)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objective:

- *To introduce the basics of mass transfer. In particular, students will be introduced to principles of diffusion, gas absorption, humidification operations, drying and crystallisation with an engineering perspective. They will be familiarised with equipments used in industries for effecting mass transfer operations.*

Module – I

Introduction to Mass Transfer and Diffusion - Molecular diffusion in liquids and gases -- Fick's Law for Molecular Diffusion - - Steady state diffusion under stagnant and laminar flow

conditions - Pseudo steady state diffusion - Diffusion through a varying cross sectional area -

Diffusivity measurements and prediction, multi-component diffusion. Principles of Unsteady state and Convective Mass Transfer: Convective mass transfer coefficients - theories of diffusion in turbulent flow, mass, heat and momentum transfer analogies. Derivation of Mass Transfer coefficients in Laminar flow – Mass Transfer for flow inside pipes - Mass Transfer for flow outside solid surfaces - Diffusion of gases in porous solids and capillaries –

Interface mass transfer, diffusion in solids.

Equipment for gas-liquid operations, tray towers, ventury scrubbers, wetted wall towers, spray towers and spray chambers, baffle towers and packed columns.

Module – II

Gas absorption : Absorption conditions of equilibrium between liquid and gas, The Henry's law - the mechanism of absorption and desorption between phases - Single stage Equilibrium contact - Counter current Multiple stage contact - Analytical Equations for Counter current stage contact (The Kremser Equations) - interphase mass transfer, liquid and gas side resistance. Design of absorbers - Liquid phase hold up - Pressure drop - Loading, flooding in packed towers. Absorption of one component, overall coefficients, dilute solution. Non-isothermal operations. Multicomponent absorption : Absorption with chemical reaction.

Module – III

Humidification : General theory, definition of absolute humidity- humid volume, humid-heat total enthalpy, adiabatic saturation temperature, wet-bulb temperature and psychrometric chart Enthalpy calculations involved in the following operations : Adiabatic humidification and dehumidification processes, cooling towers and related equipments, Evaluation of heat and mass transfer coefficients, Theory and calculations of Water cooling towers - Types of cooling equipments. Dehumdification - hot gas quenching towers - spray ponds.

Module – IV

Drying : Equilibrium between a wet solid and drying air. Batch drying equipment, rate of drying curve, time of drying continuous drying equipments, calculation of rate drying - Design of batch and continuous dryers.

Crystallisation: Factors governing nucleation and crystal growth rates, growth and properties of crystals, saturation, nucleation crystallisation rate and growth kinetics. Effect of impurities on crystal formation, effect of temperature on solubility, fractional crystallisation, caking of crystals, crystallisers batch crystallisers, tank crystallisers, evaporators. Use of vacuum continuous crystallisers, controlled growth of crystals, classification of equipments and typical crystallisers. Controlled growth of crystals. Principles of design of crystallisers. MSMPR crystallisers.

References:

1. Treybal R. E., *Mass Transfer Operations*, 3rd Edn., MGK, 1980.
2. Coulson J. M. and Richardson J.F., *Chemical Engineering*, Vol.I, Ed.3.
3. Coulson J.M. and Richardson J.F., *Chemical Engineering Vol 2.*, *Unit Operations,* Edn.3., Permom Press, 1978.
4. Philip C. Wankat, *Equilibrium Stage Separations*, Prentice Hall, 1989.
5. Foust A. S. Wsenzel, L. A. Clump, C. W. Naus and L. B. Anderson, *Principles of Unit Operations*, 2nd Edn., Wiley, 1980.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be three questions each from modules I and II, and two questions each from modules III and IV.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course Outcome:

After successful completion of this course, students will be able to solve problems involving mass transfer by diffusion. They will be able to do process design of gas absorbers, humidification equipments, dryers and crystallisers.

13.602 CHEMICAL REACTION ENGINEERING II (H)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objectives:

Students will be introduced to the design of non-isothermal reactors, reactors with non-ideal flow behaviour, heterogeneous reactions, catalysed reactions and fluid particle reactions.

Prerequisite: **13.504** Chemical Reaction Engineering I (H)

Module – I

Non-ideal Flow
Residence time distribution for chemical reactors: General characteristics - RTD functions. Measurement of the RTD - pulse input, step tracer input, integral relationships, mean residence time, other moments of the RTD, Normalized RTD function E(theta), Interval age distribution. RTD in ideal reactors: Batch and plug flow reactors, single CSTR RTD, Laminar flow reactor, PFR/CSTR series RTD. Reactor modelling with RTD - use of RTD to determine conversion. RTD models - segregation models, tanks in series model, the dispersion model. Conversion for the tanks-in-series model, fitting the dispersion model for small extents of dispersion and large extents of dispersion. Models for small deviations from plug flow and long tails. Mixing of fluids - self mixing of fluids - degree of segregation, early and late mixing of fluids.

Module – II

Non isothermal reactor design - Temperature and pressure effects - single reactions : Heat of reaction from thermodynamic, heat of reaction and temperature, equilibrium constants from thermodynamics, equilibrium conversion, adiabatic temperature and equilibrium, general graphical design procedure, optimum temperature progression.
Heat effects: adiabatic operations and nonadiabatic operations, Nonisothermal continuous flow, reactors at steady state, application to the CSTR, adiabatic tubular and batch reactor, steady state tubular reactor with heat exchange. Product distributions and temperature for multiple reactions.

Module – III

Heterogeneous Reactions
Catalysis and catalytic reactors: Catalysts, types of catalysts, catalyst properties, steps in a catalytic reaction, adsorption equilibrium constant, desorption, surface reaction, rate limiting step, contacting patterns for two phase systems. Development of design equations for ideal mixed batch reactor, plug flow tubular reactor and perfectly mixed continuous stirred tank reactor for heterogeneous systems. Heterogeneous data analysis for reactor design, deducing the rate laws from the experimental data, catalyst deactivation,

deactivation mechanisms, weight loss. Diffusion and reaction in porous catalysts- effective diffusivity, tortuosity -modelling of diffusion with reaction on a spherical catalysts. Thiele Modulus, internal effectiveness factor, Overall effectiveness factor. Estimation of diffusion and reaction limited regimes - Weisz – Prater criterion for internal diffusion, Mears criterion for external diffusion.

Module – IV

Fluid Particle Reactions (Non catalytic)

Selection of a model: Unreacted core model for spherical particles of unchanging size, model development for diffusion through gas film, ash layer, and chemical reaction controls. Rate of reaction for shrinking spherical particles - chemical reaction controls, diffusion controls application to design.

Fluid-fluid reactions - Rate equations, Kinetic regimes for mass transfer and reactions, rate equation for instantaneous and fast and slow reactions, two film theory, film conversion parameters..

References:

1. Levenspiel Octave, *Chemical Reaction Engineering*, Third Edition, John Wiley & Sons.
2. Scott Fogler H., *Elements of Chemical Reaction Engineering*, Prentice Hall of India.
3. James J Carberry, *Chemical &Catalytic Reaction Engineering*, McGraw Hill.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be three questions each from modules I and II, and two questions each from modules III and IV.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course Outcome:

On successful completion of this course, students will be able to design process reactors using advanced concepts.

13.603 HEAT TRANSFER OPERATIONS – II (H)

Teaching Scheme: 2(L) - 2(T) - 0(P) **Credits**: 4

Course Objectives:

The course outlines application of the fundamental theory and concepts learned in the first part to the solutions of practically relevant chemical engineering problems. A step into the aspects of process design principles of various heat transfer equipment will be taken up in this course. Even though the course is primarily designed to meet the requirements of an undergraduate chemical engineering course on heat transfer, it will be useful for the practicing engineers to refresh with fundamental and technical information.

Module – I

Classification of heat exchangers: Classification according to transfer processes: Indirect-Contact heat exchangers, direct-contact heat exchangers; Classification according to number of fluids; Classification according to surface compactness: gas-to-fluid exchangers, liquid-to-liquid and phase-change exchangers; Classification according to construction features: tubular heat exchangers, plate-type heat exchangers, extended surface heat exchangers, regenerators; Classification according to flow arrangements: single-pass exchangers, multi-pass exchangers; Classification according to heat transfer mechanisms.

Basic construction of a shell and tube heat exchanger with details of the various parts, concept of overall heat transfer coefficient- derivation of expression for LMTD and overall heat transfer coefficient, concept and types of fouling, fouling factors, determination of overall heat transfer coefficient with and without fouling.

Heat exchanger analysis, concept of sizing and rating problems. Numerical problems on rating problems. Concept of logarithmic mean temperature difference and its correction factor, Heat exchanger analysis using LMTD method in parallel flow, counter flow exchanger, cross flow and multi-pass heat exchangers, Temperature – distance plots for different flow arrangements in single and multi-pass heat exchangers. Determination of area, length, number of tubes required for a given duty in different configurations using LMTD method of analysis.

Concept of Effectiveness- NTU method, definition of effectiveness, effectiveness NTU relations for single pass exchangers in counter-flow and parallel flow configurations, -development of equations for effectiveness for parallel and counter-flow configurations, Determination of area, length and number of tubes using Effectiveness- NTU method, use of effectiveness- NTU charts for design of various heat exchanger configurations, *(the students will be permitted to use the Effectiveness- NTU charts in the examination hall),* interpretations of effectiveness-NTU plots.

Module – II

Double pipe heat exchangers: - construction, various steps for the design of double pipe heat exchangers.

Thermal design of agitated vessels, empirical correlations for individual heat transfer coefficients. Construction of compact heat exchangers:

Plate heat exchangers, design considerations of spiral heat exchangers. General selection guide lines for major heat exchangers types.

Determination of individual heat transfer coefficients using Wilson's plot, Compact heat exchangers - heat transfer and flow characteristic for specific configurations.

Heat transfer augmentation: General study of various methods available heat transfer augmentation for heat transfer with and without change of phase. Different types of active and passive enhancement techniques in systems involving forced convection with and without phase changes.

Heat Transfer augmentation using extended surfaces: Detailed study of heat transfer augmentation using extended surfaces:- Types of extended surfaces (fins), General conduction analysis of fins, boundary conditions. Reduction of general equation to determine temperature distribution and heat flux for fin of uniform cross section for infinitely long fin and fin with insulated tip (Derivations required). Expression for temperature distribution and heat flux for fin of uniform cross section with convective boundary condition at the fin tip (No derivation is required). Effectiveness of fins-justification for providing fins on a surface; efficiency of fins-expression for fin efficiency. Principle of fins for temperature measurement. Numerical problems of practical importance.

Module – III

Evaporation: Principle of Evaporation, types of evaporators- their construction and operation:- Natural circulation evaporators, short tube vertical or calandria type evaporators, basket type vertical evaporators, long tube vertical evaporators, forced circulation evaporators, falling film evaporators, climbing or rising film evaporators, agitated thin film evaporators, the plate evaporator. Evaporator auxiliaries: - vacuum devices, steam traps and its variants, entrainment separators.

Single effect and multiple effect evaporators, Performance of evaporators, capacity and economy of evaporators, factors affecting the performance of evaporators. Overall heat transfer coefficient, effect of liquid head and boiling point elevation. Material and energy balances for single effect evaporator and the calculations on single effect evaporator. Temperature profile in eavaporators.

Multiple effect evaporators: temperature profile of liquids in the evaporator, enthalpy of solution, Different feeding arrangements in multiple effect evaporators – their merits and demerits.

Multiple effect evaporator calculations. Evaporator selection considerations. Vapour recompression evaporators- Mechanical and thermal recompression- Energy balance, numerical problems.

Module – IV

Boiling and Condensation: - Dimensionless parameters in boiling and condensation. Pool boiling - Boiling curve, hysteresis in the boiling curve, mechanism of nucleate boiling - modes of pool boiling, pool boiling correlations - Nucleate pool boiling - correlations - Yamagata et al correlation, Rohsenow correlation. Correlation for critical heat flux for nucleate pool boiling - Zuber correlation. Correlation for minimum heat flux - Zuber correlation. Correlations for film pool boiling. Parametric effects on pool boiling, numerical problems. Forced convection boiling - Brief over view of external forced convection boiling and internal forced convection boiling.

Different types of boilers and their Classification based on different aspects, terms associated with boiler operation: circulation rate, equivalent evaporation, factor of evaporation, boiler efficiency, boiler capacity and blow down. Heat transfer characteristics in boiler operation and determination of heat transfer rate, parameters to be considered in boiler design. Numerical problems.

Condensation: Physical mechanisms, types of condensation, factors affecting condensation, laminar film condensation on a vertical plate - detailed analysis by Nusselt to determine the heat transfer coefficient. Laminar film condensation on radial systems - condensation on spheres, horizontal tubes and for a vertical tier of horizontal tubes, condensation inside a horizontal tube, correlations, film condensation inside horizontal tubes. Drop wise condensation – correlations- Numerical problems. Comparison between drop-wise and film type condensation, promoters and inhibitors used in condensation. Effect of non-condensables on condensation. Turbulent film condensation.

References:

1. Ramesh K. Shah and Dušan P. Sekulic, *Fundamentals of Heat Exchanger Design,* John Wiley & Sons, Inc. 2003.
2. M.Necati. Ozizik, *Heat transfer - A basic Approach,* McGraw-Hill College, 1985.
3. Binay K. Dutta, *Heat Transfer- Principles and Applications*, Prentice Hall of India.
4. Geankopolis C J, *Transport Processes and Separation Process Principles*, Prentice Hall of India, 4th Edition, Eastern Economy Edition, 2004.
5. Holman J P, *Heat Transfer*, McGraw Hill Book Co., 1992.

6. Incropera F P and DeWitt D P, *Introduction to Heat Transfer,* 2nd Ed John Wiley, New York, 1996.
7. Kern D Q, *Process Heat Transfer*, McGraw Hill Book Co., 1997.
8. Coulson J M and Richardson J F, *Chemical Engineering,* Volume 1, Pergamon Press, 1999.
9. Kothandaraman C.P, *Heat and Mass Transfer Data Book,* New Age International, India.
10. Holman, J.P., *Heat Transfer*, 9th Edn., McGraw-Hill, 2008.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Note: Part B questions should have at least 50 % numerical problems. *There could be numerical problems in part A also.*

Note to question paper setters:

Reference ***No. 9*** *indicated in the list of references is allowed in the examination hall, which may be mentioned along with the directions to be provided on the facing sheet of the question paper. Steam tables are also permitted in the examination hall. No other charts, tables and codes are permitted in the Examination hall. Necessary relevant data shall be given along with the question paper by the question paper setter.*

Course Outcome:

Upon successful completion of this course, the students shall become familiar with the principles and applications of heat transfer in diverse process industries. This knowledge shall equip them to design heat transfer equipments, involving heat transfer with and without change of phases suiting diverse process needs. The course further provides the students the knowledge of the various heat transfer equipments, their construction, fabrication details parts and working of the units.

13.604 PROCESS DYMANICS AND CONTROL (H)

Teaching Scheme: 2(L) - 2(T) - 0(P) **Credits**: 4

Course Objective:

This course aims at introducing the students with basic concepts of modelling, analyzing and designing process controllers for dynamical systems usually encountered in process industries.

Module – I

Introduction to process control concepts

Introduction with a suitable example to bring out concepts like *feedback control*, *feedforward control*, *negative feedback* and *positive feedback*. Importance of study of dynamics for control purpose. Generalized objectives of chemical process control: Illustrative examples to show how the effect of external disturbances are suppressed, how a process is stabilized and how an optimization of the overall performance is carried out. Classification of variables in a chemical process. Typical design elements of a control system. Control aspects of a complete chemical plant. A brief study of various hardware elements of a typical control system. Sensors for measuring devices. Sensors for flow, pressure, temperature, composition etc. Transmission lines. Final control elements. Use of digital computers in process
control.

Development of a mathematical model for control purpose

State variables and state equations of chemical processes. Transport rate equations, kinetic rate equations, reaction and phase equilibria relationships, equations of state. Dead time. Mathematical models of CSTR. mixing process, tubular heat exchangers and binary distillation columns. Input-output models of stirred –tank- heaters, mixing processes and such physical systems. Degrees of freedom and process controllers. Linearization of nonlinear systems (systems with one and two variables). Deviation variables. Linearization of nonisothermal CSTRs. Introduction to state space models concepts. State space model development of simple dynamic systems.

Module – II

Laplace Transforms and Transfer Functions.

Definition of Laplace Transforms (LT). LT of the following: exponential, trigonometric, step, pulse, impulse and translated functions, derivatives and integrals. Initial value theorem, final value theorem. Inversion of Laplace Transforms. Methods of solving Ordinary Linear Differential Equations (OLDE) by using LT. Examples. Transfer functions of systems with single input. Transfer function matrices of systems with multiple outputs. Development of the transfer function matrix for a CSTR. Representation of transfer functions with block diagrams. Block diagram algebra. Poles and Zeros of transfer functions. Qualitative nature of response of dynamical systems.

Dynamic behavior of Low Order Systems and Pure delay Systems.
Dynamic systems with a capacity for mass storage and energy storage, Pure capacitive process, Response of pure capacitive process, Dynamic response of first order lag system. Effect of parameters on the response of a first order system. First order systems with variable time constants and gain. Second order systems. Damping factor/coefficient. Underdamped, critically damped and overdamped responses. Characteristics of standard underdamped dynamic systems used as a measure of performance. Approximation of multicapacity process with second order models. Interacting and noninteracting capacities in series with examples. Manometer dynamics. Dynamics of tanks -in –series liquid level systems. N capacities in series. Jacketted heat exchange vessels. Systems with dead time. Systems with inverse response.

Module – III

Analysis of Feedback Control Systems: Types of feedback controllers, Proportional (P), Proportional Integral (PI) and Proportional Integral Derivative (PID) type of controllers. Parameters of PID type controllers. Block diagrams and closed loop responses. Closed loop response of the liquid level in a tank. Closed loop temperature response of a tank heater. Effect of proportional, integral and derivative control actions on the response of a controlled process. Effect of composite control actions.

Stability analysis of Feedback Systems: The notion of stability, Characteristic equation, Routh-Hurwitz criterion for stability. Root locus analysis. Frequency response, Bode stability criterion, Bode diagrams, Nyquist stability criterion, Nyquist plots. Frequency response of closed loop systems.

Module – IV

Design of Feedback Controllers: Outline of the design problems. Simple Performance criteria, Time-integral performance criteria, Selection of type of feedback controllers. Design of Feedback Controllers by Frequency Response Techniques. Gain and Phase margins, Controller tuning, Zeigler – Nichols Tuning technique, Cohen and Coon tuning method.

A brief introduction to advanced control systems: Only familiarity of the terms like *dead-time compensation, cascade control, selective control, split –range control, feed forward control, ratio control, adaptive control, inferential control, distributed control, direct digital control and supervisory control*.

References:

1. George Stephanopoulose, *Chemical Process Control*, An *Introduction to Theory and Practice*, Prentice Hall of India, New Delhi 1999.
2. Coughnowr, *Process Systems Analysis and Control,* McGraw Hill, Singapore, Second Edition, 1991.
3. W. L. Luyben, *Process Modeling, Simulation and Control for Chemical Engineers*, McGraw Hill Singapore, 1990.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course Outcome:

On doing this course, students will be able to analyze simple dynamic systems, develop dynamic models suitable for designing controllers and use them for designing classical controllers..

13.605 NUMERICAL METHODS FOR PROCESS ENGINEERS (H)

Teaching Scheme: 2(L) - 2(T) - 0(P) **Credits:** 4

Course Objectives:

This course associates the most common numerical methods used in engineering to solve chemical engineering problems. It also helps the student to select appropriate numerical methods for particular problem classes based on strengths and weaknesses of available techniques.

Module – I

High speed computations using digital computers. Computer arithmetic, Error analysis. Approximation of functions- Chebyshev polynomials Economized power series, Rational functions, Fourier series. Methods of fitting models to data. Empirical relations. Numerical solution of nonlinear, transcendental and polynomial equations.

Linear interpolation methods: Bisection method, Secant method, False position method, Birge- Vieta method, Newton Raphson method, Mullers method, Fixed point iteration method, Bairstow's method, QD algorithm, Chebyshev's method, Graeffe's root squaring method, Newton Raphson method for system of nonlinear equations.

Module – II

Linear Algebraic Equations: Physical problems modeled with set of linear algebraic equations, Solution of sets of linear algebraic equations. Gauss elimination, Gauss- Jordan method, LU decomposition, Crout reduction, Triangular decomposition, Iterative methods, Jacobi method, Gauss- Seidel iteration, Relaxation method, Eigen value problems- Power method, Jacob's method, Given's method.

Finite differences: Forward, backward and central differences. Properties and relations between finite difference operators, Property of difference of a polynomial, factorial polynomial and reciprocal factorial function. Difference equations.

Module – III

Interpolation with Equal Intervals: Gregory- Newton forward interpolation formulae, Central difference interpolation formulae, Gauss's forward and backward interpolation formulae, Stirling's interpolation, Bessel's interpolation, Laplace- Everet interpolation. Interpolation with Unequal Intervals: Lagrangian polynomials, Divided differences, hermite interpolation, Piecewise linear interpolation, Cubic splines, Bezier curves and B- splines.

Numerical Integration and Differentiation: Derivatives using Newton's forward and backward interpolation formulae. Use of Stirling's formula, Undetermined coefficients and Finite difference. Newton- Cotes Quadrature formula, Trapezoidal rule, Composite Trapezoidal rule, Simpson's rule, Boole's rule, Romberg integration. Gaussian Quadrature, Gauss- Legendre integration. Lobatto integration, Adaptive integration, Double integrals.

Module – IV

Ordinary Differential Equations (ODE): Physical examples- The spring- mass problem, Initial value problem, Taylor- Series method, Euler's method, Modified Euler's method, Runge-Kutta method, Multi- step methods- Predictor- Corrector methods, Adams- Moulton method, Adams- Bashforth method, Boundary Value Problems: Partial Differential Equations (PDE): Types of PDE, Physical examples: Temperature distribution in a rod, Temperature distribution in a slab, Solution methods: Shooting method, Alternating direction implicit method. Types of partial differential equations: Solution techniques for the Heat equation and the Wave equation in one and two dimensions- Numerical solution of Laplace equation.

References:

1. Curtis F. Gerald and Patrick O. Wheatley, *Applied Numerical Analysis*, Pearson Education Asia, Sixth Edition, 2002.
2. T. Veerarajan and T. Ramachandran, *Numerical Methods with Programs in C*, Second edition, TMH, 2006.
3. M. K. Jain, S. R. K. Iyengar and R. K. Jain, *Numerical Methods for Scientific and Engineering Computation*, New Age International Publishers, 2007.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be three questions each from Module I and Module II, and two questions each from Module III and Module IV.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course Outcome:

On successful completion of this course, students will be able to solve process engineering problems by selecting the most efficient and suitable method commonly used in practice.

13.606.1 BIOPROCESS TECHNOLOGY AND FERMENTATION ENGINEERING (H) (Elective II)

Teaching Scheme: 2(L) - 1(T) - 0(P) **Credits**: 3

Course Objective:

In this course, students will be introduced to basics of Bioprocess Technology and Fermentation Engineering. In particular they will be introduced to design of fermentation reactors, production of commercially important organic acids, proteins, biofertilizers, biopesticides etc.

Module – I

A historical overview of industrial fermentation process – traditional and modern biotechnology. A brief survey of organisms, processes, products relating to modern biotechnology-industrially useful microorganisms. Process flow sheeting – block diagrams with industrial pictorial representation for various equipments. Raw materials for fermentation process: Isolation, preservation and improvement of industrial micro-organisms for overproduction of primary and secondary metabolites. Medium requirements for fermentation process carbon, nitrogen, minerals, vitamins and other nutrients. Examples of simple and complex media. Basic design of the fermenter, overview of fermentation processes.

Module – II

Production and purification of primary metabolites : Industrial processes for the manufacture with the important engineering problems involved in the manufacture of the following products with flow diagram, reactions and conditions:- Organic acids-citric acid, lactic acid itaconic acid and acetic acid and other commercially important organic acids; amino acids -glutamic acid, lysine, phenyalanine, aspartic acid and other commercially important amino acids; alcohols:- ethanol, acetone and butanol.

Production of secondary metabolites :- Industrial production processes for various classes of secondary metabolites: antibiotics: beta-lactams-penicillin and cephalosporin; aminoglycosides- streptomycin, kanamycin; macrolideserythromycin, quinines, aromatics; commercially important vitamins and steroids.

Module – III

Production and purification of enzymes and other byproducts: Microbial production of industrial enzymes: proteases, amylases, lipases and cellulases. Production of biofertilizers-manufacture, formulation and utilization.

Biopesticides:- Characteristics of biopesticides. Important biopesticides- Bt-toxin, Kasugamycin, Beauverin, Devine and Collego. Biopreservatives- Nisin; biopolymers- Xanthan gum and PHB; single cell protein.

Beverages:- production of beverages, beer, wine, microbes in baking- production of baker's yeast, milk products. Bioremediation- microbes in mining, ore leaching, oil recovery, waste water treatment, biodegradation of non cellulose and cellulosic wastes for environmental conservation.

Module – IV

Production of modern biotechnology products: Production of recombinant proteins having therapeutic and diagnostic applications, production of vaccines. Production of monoclonal antibodies. Products of plant and animal cell culture.

Enzymes: Isolation and purification of commercially important enzymes: Extraction of enzymes, preparation of crude enzymes, purification and characterization of enzymes from plant, animal and microbial sources. Application of enzymes in industry, analytical purposes and medical therapy.

References:-

1. Casida Jr. L. E., *Industrial Microbioloy*, New Age International (P) Ltd.
2. Presscott, Dunn, *Industrial Microbiology*, Agrobios (India).
3. Wulf Cruger and Anneliese Crueger, *Biotechnology: A Textbook of Industrial Microbiology*, Panima Publishing Corporation.
4. Murrey Moo and Young, *Comprehensive Biotechnology*, Pergamon.
5. Palmer T. Colphon, *Enzymes: Biochemistry, Biotechnology, Clinical Chemistry*, Horwood Publishing.
6. Jackson, A.T., Process engineering in biotechnology, Prentice Hall.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course Outcome:

On successful completion of this course, students will be able to design conventional fermenters, will have a knowledge of production process of various biotechnology products.

13.606.2 ELECTROCHEMICAL TECHNOLOGY (H) (Elective II)

Teaching Scheme: 2(L) - 1(T) - 0(P) **Credits**: 3

Course Objective:

In this course, students will be introduced to the basics of electrochemical technology.

Module – I

Electrodes and separators for the electrolytic production of inorganic chemicals – preparation, characteristics and applications of graphite, magnetite, lead dioxide coated anodes, noble metal coated anodes, noble metal oxide coated anodes, spinal anodes, Perovskite anodes, steel cathodes, coated cathodes, diaphragms and ion exchange membranes. Electrolytic production of sodium hypochlorite, chlorates, bromates and iodates of sodium and potassium, sodium, potassium and ammonium perchlorates, perchloric acid, potassium and ammonium persulphates, hydrogen peroxide, potassium permanganate, cuprous oxide and maganese dioxide.

Module – II

Basic principles, reaction mechanisms, effect of operating variables, cell design and operating characteristics of industrial cells. Production of hydrogen by water electrolysis. Electrodialysis and its application to desalination of water electrolysis and waste recovery.

Basic principles of Electro organic chemistry, constant current electrolysis, controlled potential electrolysis, material yield, current efficiency, selectivity and energy consumption for electro organic synthesis. Paired synthesis with example.

Cathodic reduction of carbonyl compounds, nitro compounds, unsaturated compounds, nitriles and oximes.

Module – III

Electrohydrodimerization and cathodic coupling reactions, cathodic reactions using mediators. Anodic halogenation, oxidation through redox carriers – metal ion, non-metal ion and organic mediators. Anodic coupling reactions.

Kolbe synthesis, mechanism and applications. Anodic oxidation of aromatic hydrocarbons and phenol.

Anodic substitution reactions: alkoxylation, acetoxylation, cyanation and acetamidation.

Electro polymerization. Anodic and cathodic polymerization with example (anionic polymerization, cationic polymerization and radical polymerization).

Module – IV

Electrochemical preparation of conducting polymers such as polyacetylene, polypyrrole, polythiophene, polyaniline and their applications (excluding mechanism of polymerization). Industrial Electro organic processes such as adiponitrile from acrylonitrile, dimethyl sebacate from monomethyl adipate, Tetra alkyl lead from alkyl chloride, perfluorooctanoic acid from octanoylchloride, Aromatic aldehydes from toluenes. Electrochemical fluorination of organic compounds - Electrochemical perfluorination, Electrochemical selective/partial fluorination with examples.

References:-

1. Pletcher D. and F. C. Walsh, *Industrial Electrochemistry*, Chapman and Hall, London, 1990.
2. Kuhn A. T., *Industrial Electrochemical Process*, Elsevier Publishers, 1971.
3. Baizer M. M., *Organic Electrochemistry*, Dekker Inc, New York, 1983.
4. Riti M. R. and F. H. Covitz , Marcel Dekker, *Introduction to Organic Electrochemistry*, Inc. New York 1994.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course Outcome:

On successful completion of this course, students will be able to apply the concepts of electrochemical engineering for solving industrial application problems.

13.606.3 SOLAR ENERGY ENGINEERING (H) (Elective II)

Teaching Scheme: 2(L) - 1(T) - 0(P) **Credits**: 3

Course Objective:

In this course students will be introduced to methods for utilising solar energy using modern design considerations.

Module – I

Source of radiation – solar constant– solar charts – Measurement of diffuse, global and direct solar radiation: pyrheliometer, pyranometer, pyregeometer, net pyradiometer-sunshine recorder Solar Non-Concentrating Collectors- Design considerations.

Module – II

Classification- air, liquid heating collectors –Derivation of efficiency and testing of flat plate collectors –Analysis of concentric tube collector - Solar green house. Design – Classification– Concentrator mounting –Focusing solar concentrators- Heliostats. Solar powered absorption.

Module – III

A/C system, water pump, chimney, drier, dehumidifier, still, cooker. Photo-voltaic cell – characteristics-cell arrays-power electric circuits for output of solar panels-choppers-inverters-batteries-charge regulators.

Module – IV

Construction concepts. Energy Storage **-**Sensible, latent heat and thermo-chemical storage-pebble bed etc. materials for phase change-Glauber's salt-organic compounds. Solar ponds.

References:-

1. Yogi Goswami D., Frank Kreith, J. F. Kreider, *Principles of Solar Engineering*, 2nd Edition, Taylor & Francis, 2000, Indian reprint, 2003.
2. Edward E. Anderson, *Fundamentals for Solar Energy Conversion*, Addison Wesley Publ. Co., 1983.
3. Duffie J. A and Beckman, W .A., *Solar Engineering of Thermal Process*, John Wiley, 1991.
4. Tiwari G. N. and M. K. Ghosal, *Fundamentals of Renewable Energy Sources*, Narosa Publishing House, New Delhi, 2007.
5. W. Shepherd and D. W. Shepherd, *Energy Studies*, Second Edition, Imperial College Press, London, 2004.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course Outcome:

On successful completion of this course, students will be able to design simple solar equipments, apply basic knowledge to harness solar energy for meeting today's energy needs.

13.606.4 PROJECT ENGINEERING (H) (Elective II)

Teaching Scheme: 2(L) - 1(T) - 0(P) **Credits**: 3

Course Objective:

To impart basic knowledge in project planning, plant process design, economic evaluation and financial control.

Module – I

Introduction-Development of project-Research and development: Bench scale of experiments - pilot plant studies- Semi commercial plant Process design and Engineering: Process flow chart material and energy balance.

Module – II

Process design and building designs-equipment specifications- Selection of Equipments and materials-Plant layout- Scale modelling- piping design and layout.

Plant location and site selection- preliminary dates construction projects - site development

foundation - Erection and site fabrication –Construction- Alignment and insulation- Start up and commissioning- Trial runs- Guarantees sums and hand over.

Module – III

Company formation process license- Technology Transfer- statutory sanctions- contracts and contractors- financing with special reference to financial institutions in India, personnel recruitment and training.

Economic evaluation of projects- Capital requirements and cost of production-profitability-Break even analysis and minimum cost analysis.

Module – IV

Budgeting and financial control- Depreciation and Taxes- Insurances- Technical advancement and inflation-Financial statements Project scheduling: Bar chart, CPM, PERT methods.

References:-

1. Peters and Timmerhaus, *Plant Design and Economics for Chemical Engineers* 1980.
2. Vilbrant and Dryden, *Chemical Engineering Plant Design,* TMH, 1975.
3. Bhasin S. D., *Project Engineering of Process Plants*.
4. Davies G. S., *Process Engineering Economics,* Chemical Engineering Curriculum Development Centre, IIT Madras.

5. Anilkumar, *Chemical Process Synthesis and Engineering Design*, TMH, 1981.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course Outcome:

On doing this course, students will be able to

- *understand the various stages of project planning and implementation*
- *analyse and design the plant process*
- *assess the economic viability and suggest financial control.*

13.606.5 OPERATIONA RESEARCH (H) (Elective II)

Teaching Scheme: 2(L) - 1(T) - 0(P) **Credits**: 3

Course Objective:

The student will able to:

- *Understand and analyze managerial problems in industry so that they are able to use resources (capitals, materials, staffing, and machines) more effectively.*
- *Gain knowledge of formulating mathematical models for quantitative analysis of managerial problems in industry.*
- *Apply skills in the use of Operations Research approaches and computer tools in solving real problems in industry.*

Module – I

Origins, nature and impact of Operations Research (OR). Development of OR as a branch of knowledge since World War II. Fields of applications of OR. Steps to be performed when an OR study is to be carried out.

Introduction to Linear Programming (LP). LP model, assumptions of LP, Graphical solution, Simplex method, Revised Simplex Method, Duality Theory and Sensitivity analysis. Economic interpretation of duality and relationship between *primal* and *dual* problems, Applications.

Module – II

Transportation Problem: Formulation, solution, unbalanced Transportation problem. Finding basic feasible solutions – Northwest corner rule, least cost method and Vogel's approximation method.

Optimality test - the stepping stone method and MODI method. Assignment model: Formulation, Hungarian method for optimal solution, solving unbalanced problem.

Dynamic Programming: Introduction, Bellman's principle of Optimality, solution of problems with finite number of stages, solution of LPP by dynamic programming. Integer Programming.

Replacement – Replacement in anticipation of failure, Individual and Group replacement. Scheduling on Machines – Two-job Two-machine problem, Johnson's algorithm, Graphical solution.

Module – III

Network Optimization Models: Terminology of networks, Shortest path problem, Minimum - spanning -tree problem, Maximal -flow problem, Travelling salesman problem, Minimum cost flow problem. Project Management: Use of network concepts to represent project management problems, Scheduling a project with PERT/CPM.

Queuing theory, Queuing Models, Exponential distribution, Birth and death processes, Basic queuing process, Single server and multiple server models.

Module – IV

Game theory – Practical applications of game theory, Two-person zero-sum games, solving simple games, mixed strategy, Graphical solution, Solving by LP. Decision Theory, Statistical decision theory, Decision making with and without experimentation, Decision Trees, Utility theory.

Inventory theory, Deterministic continuous- Review models, Deterministic periodic review models, stochastic continuous-review model, model for perishable products. Stochastic periodic review models, Large inventory systems in practice.

References:-

1. Hillier and Lieberman, *Introdu7ction to Operations Research*, Tata McGraw Hill, 2001.
2. Paneer Selvam, *Operations Research*, 2nd edition, Prentice Hall of India, 1982.
3. Taha, *Operations Research*, MacMillan.
4. Naqner and Prandtl Philips and Ravindran, *Introduction to Operations Research*, John Wiley.
5. Ackoff and Sasienie, *Fundamentals of Operations Research*, Wiley.
6. Churchman, Ackoff and Arneff, *Operations Research*, Wiley.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course Outcome:

At the end of the course, students will be able to:

- *Recognize the importance and value of Operations Research and mathematical modelling to optimally solve a wide variety of engineering and management problems.*
- *Formulate a managerial decision problem into a mathematical model.*
- *Summarize Operations Research models and do interdisciplinary research and analysis to solve real life problems.*
- *Generate mathematical model for a practical problem.*

13.606.6 PRODUCTION OF PARTICULATE SYSTEMS (H) (Elective II)

Teaching Scheme: 2(L) - 1(T) - 0(P) **Credits**: 3

Course Objective:

In this course, students will be introduced to the basics of particulate systems. They will be introduced to the methods of characterizing particulate solids, production methods for agglomerates and atomization.

Module – I

Characterization of solid particles- shapes and sizes- Sampling Techniques for solids: Tabling, coning and quartering etc- isokinetic sampling for suspensions, Production of particulate system: size reduction fundamentals, ultra grinding-granular flows-storage of solids-Pneumatic transportation, flow in bins, silos etc.

Module – II

Introduction of agglomerisations- Pelletizing, briquetting, extrusions, granulation, tabletting etc. - Role of binders for agglomerisation- Product characteristics: Durability, Abration and Drop resistance.

Agglomerization systems: The importance of mixing, Proportioning, Control- Post treatment of agglomerisation- Metering of recycle, screening- Population Balance model applications to agglomerisation systems-Applications.

Module – III

Introduction to Atomization- Applications- Break up of drops- Disintegration of liquid jets and sheets- Drop size distribution: mean diameter- Drop size dispersion Different types of Atomizer- Pressure Atomizers, Rotary Atomizers, Air assist Atomizer, Ultrasonic atomizers, Effervescence Atomizers etc.

Module – IV

Flow in porous media. Characterization of granular solids. Characterization of particles: absolute density, apparent density, surface area, porosity, pore-size distribution. Particle-size distribution: dimensions and forms, determination methods. Particle dynamics: force balance in the particle, drag coefficient, terminal velocity. Porous beds. Definition of important variables: bed porosity, superficial velocity, interstitial velocity. Types: fixed bed, fluidized bed, spouted bed, pneumatic and hydraulic transport.

References:

1. Arthur H. Lefebvre, Atomization and Sprays, Hemisphere Pub.co, 1989.
2. Nasr. G.G, Industrial Sprays and Atomization: Design, Analysis and applications, London, Springer, 2002.

3. Enrique L. J., *Spray Atomization and Deposition*, John Wiley, 1996.
4. Kesava Rao K., *Introduction to Granular Flow*, Cambridge University Press, 2008.
5. Howe M. J., *Interfaces in Materials: Atomic structures, Thermodynamics and Kinetics of solid-Vapour, Solid-Liquid and Solid-Solid interfaces*, New York, John Wiley, 1997.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course Outcome:

On successful completion of this course, students will be able to use basic knowledge and skill acquired to handle problems involving particulates in process industries.

13.607 CHEMICAL REACTION ENGINEERING LABORATORY (H)

Teaching Scheme: 0(L) - 0(T) - 3(P) **Credits**: 3

Course Objective :

This course aims at giving practical knowledge in determining reaction kinetics data experimentally using batch reactors, PFR, CSTR, FBR and Cascaded Reactors.

List of Experiments:

Determination of kinetics of first and second order chemical reactions: Batch reactor - Tubular flow reactors – PFR, PBR. Stirred tank reactors - cascade of ideal reactors. Residence time distribution (RTD) - Stirred tank - Tubular reactor - Cascade of ideal reactors - Fixed bed and fluidized bed reactors. UV Reactor

Internal Continuous Assessment *(Maximum Marks-50)*

40% - Test
40% - Class work and Record
20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

University question paper will be based on the list of experiments prescribed. Marks should be awarded as per the following guidelines.

20% - Principle and procedure(During the first 20 minutes of the examination duration, the candidates shall write submit a brief procedure of the experiment he/she is going to perform and show how they will arrive at the desired results)

25% - Conducting experiment

25% - Calculation, Results and Accuracy

30% - Viva voce (based on knowledge related to various experiments listed in syllabus)

Candidate shall submit the certified fair record for endorsement by the external examiner.

Course Outcome:

On successful completion of this course, students will be able to do experiments for getting kinetics data, analyse the data and get useful information for designing process reactors.

13.608 HEAT TRANSFER LABORATORY (H)

Teaching Scheme: 0(L) - 0(T) - 3(P) **Credits**: 3

Course Objective :

*This course is to provide practical knowledge in basics of heat transfer operations. The students will be doing experiments to determine heat transfer properties of substances under various operating conditions and geometries. Validate theories of heat transfer equipments used in process industries***.**

List of Experiments:

1. Determination of thermal conductivity of solids
2. Determination of thermal conductivity of liquids
3. Determination of emissivity for surface heat transfer
4. Determination of heat transfer coefficient by natural convection:
5. Determination of heat transfer coefficient by forced convection: Forced convection heat transfer for flow of fluids through heated ducts- Determination of forced convection heat transfer coefficients and heat verification of established correlations.
6. Determination of heat transfer coefficient of fins by natural convection
7. Determination of heat transfer coefficient for fins by forced convection
8. Forced Convection Heat transfer without Phase change: Determination of heat transfer coefficient by film-type condensation
9. Determination of boiling heat transfer coefficient by conducting pool boiling experiment: Determination of heat transfer coefficients in pool boiling heat transfer for single and multi-component systems.
10. Determination of overall heat transfer for parallel flow and counter flow in double pipe heat exchanger
11. To conduct test on heat pipe and compare the temperature distribution
12. Determination of overall and individual heat transfer coefficients and effectiveness in shell and tube heat exchanger
13. Determination of overall heat transfer coefficient in an open pan evaporator
14. Heat Transfer in Composite walls- Determination of effective thermal conductivity and overall resistance.
15. Determination of radiation constant, emissivity, natural convection and radiation heat transfer coefficient for combined convection and radiation.
16. Evaporation: Study of evaporation equipment - determination of steam economy in multiple effect evaporators.

17. Heat transfer in packed beds.
18. Heat transfer in fluidised beds
19. Transient Heat Conduction: Determination of natural Convection heat transfer coefficient using the principle of lumped and distributed parameter capacity analysis using Heisler Charts.

Note : At least 10 experiments shall be performed.

References:

1. Shankar Srinivas, Heat Transfer Operations - A Lab Manual, Chemical Engineering Education Development Centre, IIT Madras.
2. Perry and Chilton, Chemical Engineers Hand Book.
3. Fundamentals of Heat and Mass Transfer, Incropera and Dewitt, Wiley.

Internal Continuous Assessment *(Maximum Marks-50)*

40% - Test
40% - Class work and Record
20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

University question paper consists of 2 experiments based on the list of experiments prescribed. Marks should be awarded as per the following guidelines.

20% - Principle and procedure(During the first 20 minutes of the examination duration, the candidates shall write submit a brief procedure of the experiment he/she is going to perform and show how they will arrive at the desired results)

25% - Conducting experiment

25% - Calculation, Results and Accuracy

30% - Viva voce (based on knowledge related to various experiments listed in syllabus)

Candidate shall submit the certified fair record for endorsement by the external examiner.

Course Outcome:

On successful completion of this course, students will be able to determine experimentally the necessary data for designing heat transfer process and equipments.