KERALA TECHNOLOGICAL UNIVERSITY

M.Tech DEGREE COURSE

COMPUTER AIDED PROCESS DESIGN

(CHEMICAL ENGINEERING) Curricula, Scheme of Examinations and Syllabi

(With effect from 2015 admissions)

SCHEME OF EXAMINATIONS

Semester I

Exam Slot	Course No.	Name	L-T-P	Internal Marks	End Semester Exam		Credits
					Marks	Duration (hrs)	
A	09CH6111	Advanced Mathematics	3-1-0	40	60	3	4
B	09CH6121	Chemical Engineering Design I	3-1-0	40	60	3	4
C	09CH6131	Chemical Engineering Design II	3-1-0	40	60	3	4
D	09CH6141	Advanced Chemical Reaction Engineering	2-1-0	40	60	3	3
E		Electives	2-1-0	40	60	3	3
F	09CH6151	Research Methodology	1-1-0	100	0	0	2
	09CH6161	Seminar	0-0-2	100	0	0	2
	09CH6171	Computer Aided Design Lab	0-0-2	100	0	0	1
Total			**14-6-4**	**500**	**300**		**23**

Elective I

1. 09CH6115 Process Optimization
2. 09CH6125 Process Safety Engineering
3. 09CH6135 Advanced heat and mass transfer
4. 09CH6145 Project engineering of process plants

Semester II

Exam Slot	Course No.	Name	L-T-P	Internal Marks	End Semester Exam		Credits
					Marks	Duration (hrs)	
A	09CH6112	Chemical Engineering design III	2-1-0	40	60	3	3
B	09CH6122	Chemical Engineering Design IV	3-1-0	40	60	3	4
C	09CH6132	Process Modeling and Simulation	2-1-0	40	60	3	3
D		Elective II	2-1-0	40	60	3	3
E		Elective III	2-1-0	40	60	3	3
	09CH6162	Mini Project	0-0-4	100	0	0	2
	09CH6172	Lab	0-0-2	100	0	0	1
Total			**11-5-6**	**400**	**300**		**19**

Electives:II

1. 09CH6116 Design and Analysis of Experiments
2. 09CH6126 Environmental Engineering and Management
3. 09CH6136 Transport Phenomena
4. 09CH6146 Downstream Processing

Elective III

1. 09CH6166 Modern Methods of Instrumentation and Analysis
2. 09CH6176 Computational Fluid Dynamics
3. 09CH6186 Industrial Pollution Control
4. 09CH6196 Advanced Chemical Engineering Thermodynamics

Semester III

Exam Slot	Course No.	Name	L-T-P	Internal Marks	End Semester Exam		Credits
					Marks	Duration (hrs)	
A		Elective IV	2-1-0	40	60	3	3
B		Elective V	2-1-0	40	60	3	3
	09CH7163	Seminar	0-0-4	100	0	0	2
	09CH7183	Project (Phase-I)	0-0-12	50	0	0	6
Total			**4-2-16**	**230**	**120**		**14**

Elective IV
1. 09CH7117 Process Integration
2. 09CH7127 Non- Conventional Energy Sources
3. 09CH7137 Advanced Bioprocess Engineering
4. 09CH7147 Mathematical Methods in Chemical Engineering

Elective V
1. 09CH7167 Advanced Process Control
2. 09CH7177 Nanomaterials & Nanotechnology
3. 09CH7187 Separation Processes
4. 09CH7197 Polymer Composites

Semester IV

Exam Slot	Course No.	Name	L-T-P	Internal Marks	End Semester Exam		Credits
					Marks	Duration (hrs)	
	09CH7184	Project (Phase-2)	0-0-21	100	0	0	12
Total			**0-0-21**	**100**			**12**

FIRST SEMESTER

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH6111	**ADVANCED MATHEMATICS**	**3-1-0-4**	**2015**

Course Objectives

This course is intended to impart knowledge in numerical methods and statistics, which are powerful tools in engineering and also have wide areas of application.

Syllabus

Direct and iterative methods for solving systems of equations; interpolation techniques; numerical integration and differentiation; numerical solutions of ODE and PDE, probability and statistics.

Expected Outcome

Students will be able to identify and apply appropriate methods for dealing with numerical data obtained from experimental outcomes. The statistical tools will help them to analyze the results and to make better conclusions.

Text Books

1. Froberg C.E., Introduction to Numerical Analysis, Addison Wesley
2. Richard A. Johnson – Probability and Statistics for engineers(PHI)

Reference Books

1. Gerald C.F., Applied Numerical Analysis, Addison Wesley
2. Hildebrand F.B., Introduction to Numerical Analysis, T.M.H.
3. James M.L., Smith C.M. & Wolford J.C., Applied Numerical Methods for Digital Computation, Harper & Row
4. Erwin Kreysig – Advanced Engineering Mathematics (Wiley Eastern)
5. M.K.Venkitaraman – Higher Mathematics for Engineering and Science.
6. Athanasios Papoulis, S Unnikrishna Pillai - Probability, Random Variables and Stochastic Processes (McGraw Hill)
7. Jenson and Jeffreys - Mathematical Methods in Chemical Engineering (Academic Press)

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Systems of linear equations – Jacobi, Gauss Seidel, SOR methods, Direct methods: Gauss Elimination, Matrix Inversion, Thomas algorithm for tridiagonal systems; Systems of nonlinear equations - successive approximation method, methods for improved convergence, Newton Method and its variants, continuation methods for multiple solutions.	13	25%

II	Lagrange's interpolation polynomial - divided differences Newton's divided difference interpolation polynomial - error of interpolation - finite difference operators - Gregory – Newton forward and backward interpolations - Stirling's interpolation formula - interpolation with a cubic spline	7	13%
	FIRST INTERNAL EXAM		
	Numerical differentiation - differential formulas in the case of equally spaced points - numerical integration - trapezoidal and Simpson's rules - Gaussian integration - errors of integration formulas	6	12%
III	Numerical solution of ordinary differential equations- The Taylor series method - Euler and modified Euler methods - Runge–Kutta methods (2^{nd} order and 4^{th} order only) - multistep methods - Milne's predictor - corrector formulas - Adam-Bashforth & Adam-Moulton formulas - solution of boundary value problems in ordinary differential equations - finite difference methods for solving two dimensional Laplace's equation for a rectangular region - finite difference method of solving heat equation and wave equation with given initial and boundary conditions	13	25%
SECOND INTERNAL EXAM			
IV	Probability and statistics - Probability distributions – Inferences concerning means – tests of hypotheses – Inferences concerning variances – Curve fitting – The method of least squares – Multiple regression - Correlation – Analysis of variance – Factorial experimentation-Stochastic Processes	13	25%
END SEMESTER EXAM			

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH6121	**CHEMICAL ENGINEERING DESIGN I**	**3-1-0-4**	**2015**

Course Objectives

To study in detail mechanical design of process equipments and their accessories involved and to develop CAD modules for them.

Syllabus

Introduction of codes for pressure vessel design, classification of pressure vessels as per codes. Design of cylindrical and spherical shells under internal and external pressure, selection and design of closures, Design of shell for tall tower used at high wind and seismic conditions. Design of lug, skirt and saddle support including bearing plates and anchor bolts. Selection of gaskets, selection of standard flanges, optimum selection of bolts for flanges, design of flanges. Design of solid-liquid separators.

Expected Outcome

- Knowledge of IS codes
- Able to use software tool for the design of internal pressure vessels
- Able to design flanges
- Able to design vessels under external pressure
- Able to design tall vessels with heads and closures and their supports
- Able to design solid-liquid separator

Text Books

1. Brownell & Young. Process Equipment Design- Vessel Design, Wiley Eastern.
2. B.C Bhattacharya, Introduction to Chemical Equipment Design, CBS Publishers & Distributors, New Delhi.
3. B.C. Bhattacharyya and C.M. Narayanan, "Computer Aided Design of Chemical Process Equipment, Ist Edn., New Central Book Agency (P) Ltd., New Delhi, 1992.
4. M.V Joshi & Mahajan V.V., Process Equipment Design, 3rd Edn, Mac-Milan & Co India.

References

1. IS Codes

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Introduction to codes. CAD Modules for design of rectangular / cylindrical / spherical vessels under internal pressure with dished / conical heads / closures. Design of Flanges.	18	35%
	FIRST INTERNAL EXAM		
II	Design of Tall Vessels with heads / closures. Wind load / Seismic load. Design of Vessels under external pressure. Thick – walled Vessels.	17	30%
	SECOND INTERNAL EXAM		
III	Design of Supports for Short / Tall Vessels. Vertical Supports (Skirt supports, Lug supports), Horizontal Supports (Saddle Supports). Solid liquid separators: - Rotary Drum Filter. Grit chamber, Trickling filter, Cyclone separator	17	35%
	END SEMESTER EXAM		

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH6131	**CHEMICAL ENGINEERING DESIGN II**	**3-1-0-4**	**2015**

Course Objectives

1. To develop the ability of students to demonstrate knowledge in fundamentals of chemical engineering
2. To develop the ability of students to identify, formulate, analyze and solve common chemical engineering problems including physical and chemical processes or units
3. To develop the ability of students to design units or components for heat transfer to meet specific needs while observing technical, economical and safety constraints
4. To develop the ability of students to utilize experimental data, software, empirical equations and rules of thumb in the design of chemical engineering units

Syllabus

General design consideration, Introduction to simulation software in chemical engineering systems. Introduction to P&I diagram

Detailed process design of Heat exchangers- Double pipe, Shell and Tube and Finned Double Pipe Heat Exchangers, Shell and Tube Condensers

Expected Outcome

The students completing this course will be able to

1. Utilize physicochemical properties of pure and mixed fluids
2. Apply basic material and energy balances to analyze and solve problems for a unit, process or an entire flow sheet using sequential and/or process solutions by performing hand-calculations and/or using suitable computer simulation packages and software
3. Compute the implications and differences in flow regimes; quantify the effects of constrictions and pipe size on power requirements; utilize the properties of materials to select a suitable material for constructing pipes based on the flowing fluid properties
4. Utilize proper energy equations and codes & standards to calculate energy requirements for equipment, such as heat exchangers and condensers
5. Calculate heat transfer coefficients, performing steady state analysis related to different modes of heat transfer
6. Utilize empirical equations and rules of thumbs in the design of chemical engineering units

Text Books

1. D.Q. Kern, Process Heat Transfer, McGraw Hill, 1950

Reference Books

1. Coulson and Richardson, Chemical Engineering, Volume 6, Butterworth Heinemann, 1996.
2. Ernest E. Ludwig, "Applied Process Design for Chemical and Petrochemical Plants'' Volume 1, 2, 3. Gulf Publishing; 4th Revised edition (13 March 2007)
3. Harry Silla, "Chemical Process Engineering Design and Economics", M Dekker
4. Douglas Erwin P E, "Industrial Chemical Process Design", McGraw hill.
5. Alexandre C Dimian, "Integrated design and Simulation of Processes", Elsevier

Perry's Chemical Engineering HandBook, Eighth Edition, McGrawHill.

Course Plan			
Module	**Contents**	**Hours**	**Semester exam marks %**
I	General: General design consideration, Optimum design, Details of Property estimation and Material and Energy balance to special software for steady state and dynamic simulation of chemical engineering systems. Introduction to P&I diagram Design of Double Pipe Heat Exchangers: Hairpins in series, hairpins in series – parallel. Heat transfer Correlations, Pressure drop computations	17	30%
FIRST INTERNAL EXAM			
II	Shell and Heat Exchangers. Fixed tubesheet / floating head / U – tube constructions. Multipass construction. Tubesheet layout (square, triangular, rotated square layouts). Heat transfer correlations for tubeside and shellside heat transfer coefficients (Colburn's and Donohue's correlations). Correction factors for baffle configuration baffle leakages, bundle bypass and unequal baffle spacing. Number of tubes in baffle window Pressure-drop computations. Correction factors for pressure drop Design of Finned Double Pipe Heat Exchangers: Longitudinal fins. Fin efficiency. Heat transfer and pressure drop correlations	17	35%
SECOND INTERNAL EXAM			
III	Condensers (Shell and Tube): Vertical condensers, horizontal condensers. Heat transfer and pressure drop correlations for film condensation on vertical and horizontal tube bundles. Condenser – sub coolers. Split flow arrangement	18	35%
END SEMESTER EXAM			

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH6141	**ADVANCED CHEMICAL REACTION ENGINEERING**	**2-1-0-3**	**2015**

Course Objectives

The students completing this course will develop

1. Ability to determine the kinetics of homogeneous and heterogeneous reactions.
2. Ability to develop models for ideal and non-ideal reactors.
3. Skill to choose a reactor from many available alternatives.
4. Skill to design of reactors for a specific application.

Syllabus

Ideal Reactors – Models of non-ideal flow – Solid catalyzed reactions – Non catalytic – Fluid particle reactions.

Expected Outcomes

The students will be able to

1. Analyze the chemical reactors and reaction systems.
2. Describe the important aspects of homogeneous and heterogeneous reactions.
3. Apply the concepts to resolve the problems in solid catalyzed reaction
4. Design of chemical reactors for homogeneous and heterogeneous reactions by applying the concepts of non-isothermal and non-ideal situations.

Text Books

1. Levenspiel. O, Chemical Reaction Engineering, 3rd John Wiley & sons.
2. Smith, J. M., Chemical Kinetics, McGraw Hill.

Reference Books

1. Fogler, S. H., Elements of Chemical Reaction Engineering, Prentice Hall.
2. Carberry. J.J, Chemical and Catalytic Reaction Engineering, McGraw Hill.
3. Walas, S. M., Chemical Reaction Engineering Handbook of Solved Problems, Oxford Sciences.
4. Davis, M.E. and Davis, R.J, Fundamentals of Chemical Reaction Engineering, McGraw Hill.

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Ideal reactors	2	25%
	Kinetics of single reactions in Ideal reactors	2	
	Design of ideal reactors for single reactions	3	
	Single and multiple reactor systems	2	
II	Basics of non-ideal flow,	2	13%
	Models of non-ideal flow- Compartment models, axial dispersion model, tanks-in-series model	3	
	FIRST INTERNAL EXAM		
	Convection model for laminar flow Earliness of mixing, segregation and RTD	2 3	12%
III	The kinetics of solid catalyzed reactions	2	

			25%
	Pore diffusion resistance combined with surface kinetics, effectiveness factor,	3	
	Performance equation for reactors containing porous catalyst particles	2	
	Packed bed catalytic reactors, fluidized reactors.	3	
SECOND INTERNAL EXAM			
IV	Non- catalytic - Fluid –particle reactions- kinetics.	5	25%
	Non- catalytic - Fluid –particle- reactor design.	5	
END SEMESTER EXAM			

Course No	Course Name	L-T-P- Credits	Year of Introduction
09CH6115	**PROCESS OPTIMIZATION**	**2-1-0-3**	**2015**

Course Objectives

The students completing this course

1. Will develop in depth knowledge of different principles and methods of optimization.
2. Will develop a general approach for establishing the conditions for equilibrium and stability for complex systems.
3. Can analyze & solve practical chemical engineering optimization problems.
4. Can apply the knowledge of optimization to design problems.

Syllabus

Linear Algebra - Introduction to vector spaces and matrix algebra, Geometric concepts. Formulation of Optimization Problems in Chemical Engineering. Unconstrained optimization: necessary and sufficiency condition for local optimum, univariate optimization methods, Multivariate Unconstrained Optimization methods , Multivariate Constrained Optimization methods, Duality theory for nonlinear programming.

Expected Outcome

1. Understand different principles and methods of optimization.
2. Formulate an optimization problem.
3. Analyze different levels of optimization problems (univariate & multivariate, unconstrained & constrained).
4. Apply the proper optimization methods to actual Chemical Engineering based problems.

Text Books

1. T. F. Edgar and DM Himmelblau, *Optimization of chemical processes*
2. M.C. Joshi and K. M. Moudgalya, *Optimization: Theory and Practice*, Narosa Publishing.
3. S.S. Rao, *Optimization Theory and Applications*

Reference Books

1. J. Nocedal and S. J. Wright, *Numerical Optimization*, Springer Verlag.
2. Gilbert Strang, *Linear Algebra*

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Linear Algebra . Formulation of Optimization Problems in Chemical Engineering. Unconstrained optimization: necessary and sufficiency condition for local optimum, univariate optimization methods - bracketing techniques, Golden section and cubic interpolation.	10	25%
II	Multivariate Unconstrained Optimization -, Nelder-Head's method, Powell's method	4	12%
	FIRST INTERNAL EXAM		
	Steepest descent, Conjugate gradient, Newton and quasi-Newton methods	5	13%

III	Multivariate Constrained Optimization: Karush-Kuhn-Tucker conditions for local optimality, Linear Programming: Simplex, Duality	10	25%
SECOND INTERNAL EXAM			
IV	Duality theory for nonlinear programming- Lagrangean Interpolation method- Quadratic programming- Active set method- Quadratic penalty method	10	25%
END SEMESTER EXAM			

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH6125	**PROCESS SAFETY ENGINEERING**	**2-1-0-3**	**2015**

Course Objectives:

To study the principles and practice of process safety.

Syllabus:

Hazards of Chemicals- Identification of Hazard- Major Industrial Hazards, Technique for Hazard Evaluation, Consequence Analysis and Quantitative Risk Assessment, Inherent Safety and Process Intensification, Process Reliability and Human Error Analysis

Expected Outcome:

1. To describe the needs of safety
2. Implement the safety in processes.
3. Analyze the chemical hazards in plants.
4. Analyze the Process Reliability and Human Errors.

Text Books:

1. Daniel Crowl- " Chemical Process Safety" 3rd edition, Pearson Publications
2. V. C. Marshal- " Major Chemical Hazards" Ellis Harwood Ltd, Chicheser, UK 1987
3. Bhaskara Rao- "Safety in Process Plant Industries" Khanna Publications.

Reference Books:

1. Frank P. Lees- "Loss Prevention in Process Industries" ,Vol.1,2&3,Second Edn, Butterworth-Heinemann.1996
2. Guidelines for Hazard Evaluation Procedure. Centre for Chemical Process Safety.AICHE,1992
3. Ralph King, Safety in the Process Industries, Butterworth-Heinemann
4. Wells. G. L, Safety in Process Plant Design, George Godwin Ltd, London

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Special Hazards of Chemicals – Toxicity, Flammability, Explosions	1	25%
	Sources of ignition, Ionising Radiation, Pressure and Temperature deviation, Runaway reactions.	2	
	Identification of Hazard - Inventory analysis, Dow Fire and Explosion Index.	2	
	Mond Fire, Explosion and Toxicity Index.	2	
	Major Industrial Hazards - Reasons, Flixborough and Bhopal disasters.	3	
II	Technique for Hazard Evaluation - Hazard and Operability, study	2	12%
	Preliminary Hazard Analysis	2	
	What if Analysis	1	
	FIRST INTERNAL EXAM		
	Fault Tree Analysis, Event Tree Analysis	2	13%
	Failure Modes , Effects Analysis, Examples	2	

III	Consequence Analysis and Quantitative Risk Assessment-Consequence of Chemical accidents. Models for Fire, Explosion and Toxic gas dispersion. Individual and Societal Risk F-N curves, Probit function. Elements of Emergency Planning Inherent Safety and Process Intensification-The concept of Inherent Safety, Tools for Inherent Process Safety. Inherent Safety Indices. The concept of Process Intensification	1 2 1 1 2 2 1	25 %
SECOND INTERNAL EXAM			
IV	Process Reliability and Human Error Analysis-Basic Principles of Reliability engineering. Ways of improving process Reliability. Reasons of Human Error Tehnique for assessing Human error	3 2 2 3	25%
END SEMESTER EXAM			

Course No	Course Name	L-T-P- Credits	Year of Introduction
09CH6135	**ADVANCED HEAT AND MASS TRANSFER**	**2-1-0-3**	**2015**

Course Objectives

The students completing this course will develop

1. Deeper understanding on modes of heat transfer and their treatment in multi-dimensions.
2. The ability to analyze various engineering problems involving conduction, convection and radiation heat transfer
3. The ability to develop and solve boundary layer equations for various cases of heat and mass transfer
4. Knowledge to analyze and solve mass transfer cases involving multi-component diffusion
5. Understanding of interphase mass transport involving multi component systems
6. Apply the knowledge of heat and mass transfer to design problems

Syllabus

Review of conduction, convection, and thermal radiation fundamentals, steady state one- and two-dimensional conduction, transient conduction for various configurations and fins. Convection heat transfer. Molecular diffusion. Interphase transport in multi component systems.

Expected Outcome

Students will develop deeper understanding on advanced concepts of heat and mass transfer, analytical and problem solving skills on engineering problems involving the same and skill to apply the knowledge acquired in real design problems

Text Books

1. Bird et al., *Transport phenomena*, John Wiley & Sons.
2. Wetty J.R et al., *Fundamentals of momentum, heat and mass transfer*, John Wiley & Sons

Reference Books

1. Wetty J.R., *Engineering heat transfer*, John Wiley & Sons.
2. Foust A.S et al., *Principles of unit operations*, John Wiley & Sons.
3. Giedt, *Principles of engineering heat transfer*, Van Nostrand Co.

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Review of conduction, convection, and thermal radiation fundamentals, steady state one- and two- dimensional conduction, transient conduction for various configurations and fins.	10	25%
II	Convection heat transfer – Heat transfer in laminar and turbulent flows, hydrodynamic and thermal boundary layer.	5	13%
	FIRST INTERNAL EXAM		
	Integral analysis of hydro dynamic boundary layer. Exact analysis of thermal boundary layer. Heat transfer to non-	5	12%

	Newtonian fluids.		
III	Molecular diffusion – Steady state molecular diffusion, equations of change for multi component systems, use of equations of change in diffusion problems. Simultaneous diffusion and chemical reaction. Analogy between heat, mass and momentum transfer.	10	25%
SECOND INTERNAL EXAM			
IV	Interphase transport in multi component systems – Binary mass transfer coefficient in one phase, mass transfer coefficients for low and high mass transfer rates. Film theory, penetration theory and boundary layer theory of mass transfer.	9	25%
END SEMESTER EXAM			

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH6145	**PROJECT ENGINEERING OF PROCESS PLANTS**	**2-1-0-3**	**2015**

Course Objectives

To impart the basic concepts of project management and design aspects of process plants

Syllabus

Scope of project engineering - the role of project engineer - R & D -plant location and site selection - process engineering -Planning and scheduling of projects - procurement operations - office procedures - project financing - statutory sanctions- Details of engineering design and equipment selection I - Details of engineering design and equipment selection II - thermal insulation and buildings - safety in plant design - plant constructions, start up and commissioning

Expected Outcome

1. The student will acquire the knowledge to evaluate of design aspects & design options of process plant.
2. The student will be able to evaluate the technical, economic, and financial feasibility of a process plant

Reference Books

Rase & Barrow, Project Engineering of Process Plants, John Wiley

Peter S. Max & Timmerhaus, Plant design and economics for chemical engineers. Mc Graw Hill (2002).

Srinath L. S., "PERT AND CPM." affiliated east press pvt. Ltd., new york (1973)

Perry J. H.,"Chemical engineering handbook" 7th ed. Mc Graw Hill (1997).

Jellen F. C., "Cost and optimization in engineering". Mc Graw Hill (1983).

Frederick B. Plummer, Project Engineering, BH

Ernest E. Ludwig, Applied project engineering and management, Gulf Pub. Co., (1988)

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Scope of project engineering - the role of project engineer - R & D - TEFR - plant location and site selection - preliminary data for construction projects - process engineering - flow diagrams - plot plans - engineering design and drafting	9	25%
II	Planning and scheduling of projects - bar chart and network techniques	4	10%
	FIRST INTERNAL EXAM		
	procurement operations - office procedures - contracts and contractors - project financing - statutory sanctions	5	15%
III	Details of engineering design and equipment selection I - design calculations excluded - vessels - heat exchangers - process pumps - compressors and vacuum pumps - motors and turbines - other process equipment	10	25%
	SECOND INTERNAL EXAM		

IV	Details of engineering design and equipment selection II - design calculations excluded - piping design - thermal insulation and buildings - safety in plant design - plant constructions, start up and commissioning	10	25%
END SEMESTER EXAM			

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH6151	**RESEARCH METHODOLOGY**	**1-1-0-2**	**2015**

Course Objectives

Introduce the students to the field of research and give an idea on how to conceptualize their research design and how to publish their results in the knowledge database.

Syllabus

Introduction to Research methodology, Conceptualizing a research design, Application of mathematical modelling and simulation in research, Research writing and publishing

Expected Outcome

The student will be able to:

1. Formulate the research problem
2. Develop a research plan
3. Conduct the research
4. Analyze and interpret the data by various techniques
5. Publish their results

Text Books

1. Ranjit Kumar, "Research Methodology: A Step-by-step Guide for Beginners", Pearson, Second Edition
2. Kothari, C.R, "Research Methodology : Methods and Techniques", New age International publishers

Reference Books

1. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction", 2^{nd} Edition, 2001, Juta& Co Ltd.
2. J.W Bames, Statistical Analysis for Engineers and Scientists, McGraw Hill, N.York
3. Schank Fr., Theories of Engineering Experiments, Tata Mc Graw Hill Publication.
4. Willktnsion K. L, Bhandarkar P. L, Formulation of Hypothesis, Himalaya Publication.

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Research Methodology: An introduction Meaning of research,Objectives of research,Motivation in research,Applications of research,Definition of research,Characteristics of research,Types of research, Steps in research process Formulating a research problem:-Reviewing the literature,	7	25%

	Formulating a research problem, Identifying variables, Constructing hypothesis		
II	Conceptualizing a Research Design:- Definition of a research design, Need for research design, Functions of research design, Features of a good design Methods of Data Collection:- Collection of primary data,Observation method, Interview method, Collection of data through questionnaires, Collection of data through schedules.	7	25%
FIRST INTERNAL EXAM			
III	Mathematical modelling and simulation:– Concepts of modelling, Classification of mathematical models, Modelling with:– Ordinary differential equations, Difference equations, Partial differential equations, Graphs, Simulation, Process of formulation of model based on simulation.	6	25%
IV	Research writing in general:- Referencing, Writing a bibliography, Developing an outline, Writing about a variable, Interpretation of data and paper writing, Layout of a research paper, Journals in Chemical Engineering, Impact factor of Journals, When and where to publish? Ethical issues related to publishing, Plagiarism and Self-Plagiarism Software for paper formatting like LaTeX/ MS Office	6	25%
SECOND INTERNAL EXAM			

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH6161	**SEMINAR**	**0-0-2-2**	**2015**

Course Objectives

To assess the debating capability of the student to present a technical topic. Also to impart training to a student to face audience and present his/her ideas and thus creating self esteem and courage that are essential for an engineer.

Individual students are required to choose a topic of their interest from process design/design related topics preferably from outside the M.Tech syllabus and give a seminar on that topic about 45 minutes. A committee consisting of at least three faculty members shall assess the presentation of the seminar and award marks to the students based on merits of topic of presentation. Each student shall submit two copies of a write up of the seminar topic. One copy shall be returned to the student after duly certifying it by the chairman of the assessing committee and the other will be kept in the departmental library. Internal continuous assessment marks are awarded based on the relevance of the topic, presentation skill, quality of the report and participation.

Internal Continuous Assessment *(Maximum Marks-100)*

Relevance + Literature	: 10 marks
Concept / Knowledge in the topic	: 20 marks
Presentation	: 40 marks
Report	: 30 marks
Total marks	**: 100 marks**

Expected Outcome

At the end of the course the student will be able to

1. Communicate with group of people on different topics
2. Prepare a Seminar report that includes consolidated information on a topic

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH6171	**COMPUTER AIDED DESIGN LAB**	**0-0-2-1**	**2015**

Course Objectives

To study the design of process equipments using special softwares for chemical engineering systems.

Optimal design of the following equipments using softwares.

1. Shell and Tube heat exchangers , Plate type Heat Exchanger& Condensers.

2. Double Pipe Heat Exchangers, Finned Heat Exchangers.

3.Condensers (Shell and Tube) : Vertical condensers, horizontal condensers.

4. Reboilers & Vaporisers: Kettle type, Vertical Thermosyphon type.

Internal Continuous Assessment *(Maximum Marks-100)*

Regularity	: 30 marks
Record	: 20 marks
Tests, Viva	: 50 marks
Total marks	**: 100 marks**

Expected Outcome

At the end of the course the student will be able to

1. Solve complex chemical engineering problems by applying suitable numerical methods
2. Design the process equipment using design software

SECOND SEMESTER

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH6112	CHEMICAL ENGINEERING DESIGN III	2-1-0-3	2015

Course Objectives

To study in detail design of heat and mass transfer equipments and phase separation equipments which are very integral in industry

Syllabus

Reboilers & Vaporisers. Design of Multiple Effect Evaporators (MEE) .Mass and Heat Balances in MEE. BPR chart. Enthalpy — Concentration Diagrams. Solution for n effects using Gauss — Seidel / Crout' s method. Optimum number of effects. Design of dryers-Cooling Towers

Expected Outcome

1. The course will provides basic concepts, industrial practices and theoretical relationships useful for the design of process equipment
2. The students will able to a pply the principles of heat & mass transfer to engineering situations and the design of equipments involving both heat & mass transfer.

Reference Books

1. Narayanan,C.M. and B.C.Bhattacharya, Unit Operations and Unit Processes, Volume—I,CBS Publishers, New Delhi
2. Richardson, J.M., Coulson J .F. and Sinnot R. K.: Chemical Engineering Vol . 6.
3. Harry Silla, "Chemical Process Engineering Design and Economics", M Dekker
4. Douglas Erwin P E,"Industrial Chemical Process Design", McGraw Hill.
5. Kunni D., Levenspial D.: Fluidization Engineering. Wiley.
6. Perry's Chemical Engineering HandBook, McGraw Hill**.**
7. Nauman Bruce; Handbook of chemical reactor design, optimisation and scale up, McGraw Hi1l

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Reboilers & Vaporisers: Kettle type, Vertical Thermosyphon type	10	30%
FIRST INTERNAL EXAM			
II	Design of Multiple Effect Evaporators (MEE) : Classification of Evaporators. Types of feeding in Multiple Effect Evaporators (MEE). Mass and Heat Balances in MEE. BPR chart. Enthalpy — Concentration Diagrams. Solution for n effects using Gauss — Seidel / Crout' s method. Optimum number of effects.	15	35%
SECOND INTERNAL EXAM			

III	Design of dryers: Rotary dryer, Tray dryer. Cooling Towers : Water cooling by air. Psychrometric equations. Minimum (L/G) ratio. HTU — NTU concept.	14	35%
END SEMESTER EXAM			

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH6122	**CHEMICAL ENGINEERING DESIGN IV**	**3-1-0-4**	**2015**

Course Objectives

1. To develop the ability of students to demonstrate knowledge in fundamentals of chemical engineering
2. To develop the ability of students to demonstrate knowledge of physical processes encountered in chemical engineering practice including the various separation process
3. To develop the ability of students to identify, formulate, analyze and solve common chemical engineering problems including physical and chemical processes or units
4. To develop the ability of students to design units or components for mass transfer to meet specific needs while observing technical, economical and safety constraints
5. To develop the ability of students to utilize experimental data, software, empirical equations and rules of thumb in the design of chemical engineering units

Syllabus

Detailed process design of equipment for Absorption, Distillation, Multi-component Distillation, Liquid-Liquid extraction

Expected Outcome

The students completing this course will be able to

1. Utilize physicochemical properties of pure and mixed fluids
2. Apply basic material and energy balances to analyze and solve problems for a unit, process or an entire flow sheet using sequential and/or process solutions by performing hand-calculations and/or using suitable computer simulation packages and software
3. Apply the fundamentals of stage operations using phase diagrams and phase equilibrium, and describe the main factors affecting them
4. Analyze stage-wise and continuous gas-liquid/ liquid-liquid separation processes by applying graphical and analytical methods for absorbers, distillation columns and extraction columns
5. Apply the basics of mass transfer operations in the design of units such as absorption, distillation columns and liquid-liquid extraction units.
6. Calculate mass transfer coefficients, performing steady state analysis
7. Utilize proper codes & standards, empirical equations and rules of thumbs in the design of chemical engineering units

Text Books

1. Robert E. Treybal, Mass-Transfer Operations, Third Edition, Mc-GrawHill, 1981
2. Christie John Geankoplis, Transport Processes and Separation Process Principles, 4th Edition

Reference Books

1. Coulson and Richardson, Chemical Engineering, Volume 6, Butterworth Heinemann, 1996.
2. Ernest E. Ludwig, “Applied Process Design for Chemical and Petrochemical Plants’’ Volume 1, 2, 3. Gulf Publishing; 4th Revised edition (13 March 2007)
3. Harry Silla, “Chemical Process Engineering Design and Economics”, M Dekker
4. Douglas Erwin P E, “Industrial Chemical Process Design”, McGraw hill
5. Alexandre C Dimian, “Integrated design and Simulation of Processes”, Elsevier
6. Perry’s Chemical Engineering HandBook, Eighth Edition, Mc-GrawHill

Course plan			
Module	**Contents**	**Hours**	**Semester exam marks %**
I	Design of Packed Bed Absorption Column: Flooding and loading. Flooding Velocity Computation. Mass transfer correlations. HTU — NTU concept	16	30%
FIRST INTERNAL EXAM			
II	Sieve Plate (Absorption / Distillation columns): Flooding Velocity Computation. Tray spacing. Active plate area. Minimum weeping velocity. Correction for entrainment. Plate stability. Liquid gradient across the tray. Total pressure drop through perforations, through aerated mass. Downcomer hydraulics. Residence time in downcomer	18	35%
SECOND INTERNAL EXAM			
III	Computer Aided Design and Analysis of Multicomponent Distillation processes by FUG (Fenske — Underwood — Gilliland) Method. Liquid - liquid extraction columns, packed columns	18	35%
END SEMESTER EXAM			

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH6132	**PROCESS MODELING AND SIMULATION**	**2-1-0-3**	**2015**

Course Objectives

1. To develop the ability in students to demonstrate the knowledge of physical and chemical processes encountered in chemical engineering practice
2. To make the students to develop the mathematical models for chemical engineering systems and solutions for those models

Syllabus

Introduction-Models, Classification and Model building. Modeling and Simulation of Lumped parameter models (steady-state and unsteady-state), Distributed parameter models (steady-state and unsteady state)

Expected Outcome

The students completing this course will be able to

1. Define, List and Explain the classification of mathematical models
2. List and Explain the steps involved in mathematical modeling
3. Describe the fundamental, the physical meaning and the equations governing the processes
4. Formulate and Validate models
5. Demonstrate the model solving ability for various processes/unit operations

Text Books

1. W.L. Luyben, "Process Modelling, Simulation and Control for Chemical Engineers", 2nd Edn., McGraw Hill Book Co., New York, 1990
2. Biquette W.B., Process Dynamics - Modeling Analysis and Simulation, Prentice Hall of India

Reference Books

1. R.E.Franks, Modeling and Simulation in Chemical Engineering, John Wiley, 1972
2. K. M. Hangos and I. T. Cameron, "Process Modelling and Model Analysis", Academic Press, 2001
3. W.F.Ramirez, Computational Methods In Process Simulation, Butterworth, 1989
3. John Ingham et.al., Chemical Engineering Dynamics - Modelling with PC Simulation, VCH Publishers
4. Amiya K.Jana, Computer Process Modelling and Computer Simulation, Prentice Hall of India

Mark E. Davis, "Numerical Methods and Modelling for Chemical Engineers", John Wiley & Sons, 1984

Course Plan

Module	**Contents**	**Hours**	**Semester exam marks %**
I	Definitions of Modelling, Simulation-classification of modelling techniques-uses and applications of mathematical modelling-basic modelling principles-fundamental laws of chemical engineering: energy equations, continuity equation, equation of motion, transport equations, equations of state, equilibrium states and chemical kinetics-sufficiency and redundancy-boundary conditions Solution methods for algebraic equations: direct and indirect methods- Solution methods for initial value and boundary value problems: Euler’s method, R-K method.	9	25%
II	Mathematical models with simulation strategies for chemical engineering systems: continuous flow tanks-open and enclosed vessel- mixing vessel	4	10%
	FIRST INTERNAL EXAM		
	Mixing with reaction - reversible reaction- steam jacketed vessel-isothermal constant and variable hold up CSTR in series- batch reactor - semi batch reactor.	6	15%
III	Mathematical models with simulation strategies for Boiling of single component liquid- open and closed vessel - continuous flow boiling - multicomponent boiling system - batch distillation-condensation- Multicomponent flash drum- ideal binary distillation column – multicomponent distillation column- Liquid extraction	11	25%
SECOND INTERNAL EXAM			
IV	Solution strategies for distributed parameter models-shooting method, finite difference methods. Mathematical models with simulation strategies for Distributed system: Double pipe liquid-liquid heat exchanger- tubular reactor with axial dispersion	9	25%
END SEMESTER EXAM			

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH6116	**DESIGN AND ANALYSIS OF EXPERIMENTS**	**2-1-0-3**	**2015**

Course Objectives

This subject provides students with the knowledge to

1. Use statistics in experimentation;
2. Understand the important role of experimentation in new product design, manufacturing process development, and process improvement;
3. Analyze the results from such investigations to obtain conclusions;
4. Become familiar methodologies that can be used in conjunction with experimental designs for robustness and optimization.

Syllabus

Introduction to the role of experimental design - Basic statistical concepts - Hypothesis testing - Analysis of variance (ANOVA) - Design of experiments - Regression analysis - Response surface methodology

Expected Outcomes

The students will be able to

1. Describe how to design experiments, carry them out, and analyze the data they yield.
2. Understand the process of designing an experiment including factorial and fractional factorial designs.
3. Investigate the logic of hypothesis testing, including analysis of variance and the detailed analysis of experimental data.
4. Learn the technique of regression analysis, and how it compares and contrasts with other techniques studied in the course.
5. Understand the role of response surface methodology and its basic underpinnings.

Text Books

1. “Design and analysis of experiments” by D.C. Montgomery, 8th edition John Wiley and sons, New York.
2. “Applied Statistics and Probability for Engineers”, by D.C. Montgomery and G.C. Runger, 5th edition John Wiley and sons, New York.

Reference Books

1. “Design and analysis of experiments” by Klaus Hinkelmann, 2ndEdn. Wiley, New York.
2. “Introduction to Probability models” by Sheldon M. Ross, 10thEdn, Elsevier, USA.
3. “Response surface methodology” byR. H. Myers, D.C. Montgomery, C. M. Anderson-Cook, 2nd.Edn, John Wiley and sons, New York.

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Introduction to the role of experimental design	2	25%
	Basic statistical concepts, sampling and sampling distribution	3	
	Hypothesis Testing	2	

	Inference about the difference in means and variances	2	
II	Analysis of variance (ANOVA) -one-way classification ANOVA	2	13%
	Analysis of fixed effects model, Estimation of model parameters	3	
	FIRST INTERNAL EXAM		
	Comparison among treatment means	2	12%
	Random effects model; randomized designs and paired comparison designs, the randomized complete block design.	3	
III	Factorial design of experiments; two-factor factorial design	3	25%
	Analysis of fixed effects model	2	
	General factorial design	2	
	Analysis of 2k and 3k factorial designs	3	
SECOND INTERNAL EXAM			
IV	Regression analysis— Simple and multiple linear regression	3	25%
	Hypothesis testing in multiple regression	2	
	Response surface methodology-the method of steepness ascent	3	
	Response surface designs for first-order and second-order models.	2	
END SEMESTER EXAM			

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH6126	**ENVIRONMENTAL ENGINEERING AND MANAGEMENT**	**2-1-0-3**	**2015**

Course Objectives

The students completing this course

1. Will be able to understand and characterize water & air pollutions and respective sources.
2. Enable for management, design of systems for solid, liquid and air pollution control

Syllabus

Waste water treatment, Concept of common effluent treatment plant (CETP). Zero discharge systems, Air pollution, global effect of air pollutants,factors affecting dispersion of air pollutants, dispersion modeling. Air pollution control of stationary sources, Noise pollution, community noise-sources, Pollution control in industries, Solid waste and hazardous waste management General guidelines of environmental impact assessment (EIA), environmental management systems (EMS) and environmental audit.

Expected Outcome

1. Understand different types of Air, water pollutions and respective sources.
2. Analyze the environmental aspects of pollution.
3. Characterize different sources of waste.
4. Manage solid & hazardous wastes.
5. Model and design water treatment system for any effluent treatment plant.

Text Books

1. Metcalf and Eddy, Waste water engineering, treatment, disposal, reuse, Tata-McGraw Hill.
2. Mahajan.S.P, Pollution control in process industries, Tata-McGraw Hill.
3. Rao.C.S, Environmental pollution control engineering, New age international (P) ltd.

Reference Books

1. Rao.M.N and H.V.N. Rao, Air pollution, Tata McGraw Hill
2. H.S Peavey et al., Environmental engineering, McGraw Hill

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Waste water treatment Modelling and Design of Activated sludge system, Advanced waste water treatment, Sludge treatment and disposal. Characteristics of domestic waste, municipal waste water treatment systems	9	25%
II	Air pollution: .Air pollution control of stationary	5	12%
	FIRST INTERNAL EXAM		
		5	13%

	Noise pollution: effect of noise pollution on people, community noise-sources & criteria, noise control.		
III	Pollution control in industries: pollution control in petroleum refineries, fertilizer industries, pulp and paper industries, textile industries, rubber processing industries, chlor-alkali industries, tanning industries, breweries, dairy, phenol plants, electroplating and metal finishing industries and cement industries	10	25%
SECOND INTERNAL EXAM			
IV	Solid waste and hazardous waste management: characteristics of solid waste, disposal methods, Resource conservation and recovery. Definitions and classification of hazardous waste, waste minimization and recycling, treatment techniques. Handling and management of hospital wastes. General guidelines of environmental impact assessment (EIA), environmental management systems (EMS) and environmental audit.	10	25%
END SEMESTER EXAM			

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH6136	**TRANSPORT PHENOMENA**	**2-1-0-3**	**2015**

Course Objectives

To develop the ability to elaborate conceptual and mathematical models, from conservation principles, to systems involving simultaneous mass, momentum, and/or heat transfer processes as well as reactions or other sources/sinks of transport for multi-component mixtures.

Syllabus

Flux laws, shell balance equations- simplification and solution to problems, use of equations of change to solve fluid flow problems, comparison of laminar and turbulent flows in circular tubes and flat plates, interphase transport – friction factors, energy equation, use of equations of change to solve heat transfer problems, equation of continuity for a multi component mixture, use of equations of change to solve mass transfer problems, simultaneous heat and mass transfer, thermal diffusion and pressure diffusion.

Expected Outcome

The students completing this course will develop

1. Understanding of the principles of transport of momentum, heat and mass.
2. The ability to set up overall balances for conservation of momentum, energy and mass and apply flux laws in balances.
3. The ability to obtain profiles for velocity, temperature and concentration from shell balance equations.
4. The ability to reduce and solve appropriate equations of change to obtain desired profiles for velocity, temperature and concentration.
5. The ability to apply the principles of transport processes to practical situations.

Text Books

1. Bird R.B, Stewart W.E & Lightfoot E.N, Transport Phenomena, John Wiley Publishers.
2. Welty J.R, Wicks C.E& Wilson.K.E., Fundementals of Momentum, Heat and Mass Transfer, John Wiley Publishers.

Reference Books

1. Frank M. White, Viscous fluid flow, McGraw Hill International
2. C.O.Bennett, J.E. Myers, Momentum, Heat and Mass Transfer, McGraw Hill

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Flux laws, shell balance equations for momentum, heat and mass transfer – simplification of equations in various coordinate systems to solve a few introductory problems- flow of a falling film, flow through a circular tube, heat conduction through composite walls, heat conduction with a chemical heat source, diffusion through stagnant gas film, diffusion with reaction.	9	25%
II	Equation of continuity, motion, substantial derivative,	6	13%

	Navier – Stokes equation, Euler equation, use of equations of change to solve fluid flow problems- flow of falling film, steady flow in a long circular tube, shape of surface of a rotating liquid, operation of a couette viscometer.		
	FIRST INTERNAL EXAM		
	Comparisons of laminar and turbulent flows in circular tubes and flat plates, interphase transport- friction factors for flow in tubes	4	12%
III	Equation of energy, use of equations of change to solve steady state problems involving heat transfer- steady flow forced convection heat transfer in laminar flow in a circular tube, tangential flow in an annulus with viscous heat generation, steady flow in a non-isothermal film, transpiration cooling.	10	25%
	SECOND INTERNAL EXAM		
IV	Equation of continuity for a multi component mixture, diffusion, convection and chemical reaction, use of equations of change to solve problems involving mass transfer-simultaneous heat and mass transport, thermal diffusion and Clusius – Dickel column, pressure diffusion and ultracentrifuge	10	25%
	END SEMESTER EXAM		

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH6146	DOWNSTREAM PROCESSING	2-1-0-3	2015

Course Objectives

In this course the students are introduced to different downstream processing techniques and their principle, scale up, design application and importance in product separation and purification operations.

Syllabus

Overview of downstream process technology, Product identification techniques. Mechanisms, principle, scale up and design of thickener, precipitation units, filtration units, distillation column, extraction column, evaporator, crystallizer and driers.

Expected Outcome

The students completing this course will develop

- Ability to describe the principles and application of major unit operations used in downstream processing; for example homogenization, centrifugation and precipitation, chromatography and membrane separation units.
- Ability to analyze and perform basic scale-up calculations for major downstream unit operations such as sedimentation, filtration, extraction, adsorption etc
- Ability to design various equipments like thickener, filtration units, distillation column. extraction column, evaporator, crystallizer and driers.

Reference Books

1. Juan A. Asenjo (Ed), *Separation processes in biotechnology,* CRC
2. Satinder Ahuja (Ed), *Handbook of Separations,* Academic Press
3. Roger. H. Harrison et.al. *Bioseparations Science and Engineering,* Oxford University press, 2004.
4. Paul. A. Belter, E.L.Cussler, Wei-Shou Hu *Bioseparations-Downstream processing for Biotechnology,*
John Wiley and sons, 1988
5. James.E.Bailey, David.F. Ollis *Biochemical engineering fundamentals,* McGraw Hill.1986
6. Syed Tanveer Ahmed Inamdar *Biochemical engineering- Principles and concepts,* Prentice Hall of India.2007
7. Richardson J.F, Harker J.H, Backhurst J.R, *Coulson and Richardson's Chemical Engineering- Vol.2:*
Particle technology and separation ***processes,*** Butterworth Heinemann. 2002
8. Nooralabettu Krishna Prasad. Downstream process Technology. PHI Learning Pvt Ltd, New Delhi. 2010

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Overview of downstream process technology: Need for downstream processing, criteria for choice of recovery processes. Cell disruption, Flocculation, Foam and bubble fractionation- Principle, operation and applications.	2	25%
	Gravity sedimentation: Mechanisms of sedimentation, Design of industrial equipments for gravity settling- thickeners, classifiers – applications in downstream processing.	2	
	Centrifugal separations: Theory of centrifugal settling, ultra centrifugation.	2	

	Filtration: Equipments for conventional filtration- filter media, pre-treatment methods, general filtration theory- Darcy's law, compressible and incompressible filter cakes, filtration cycle, scale up and design of filtration systems.	2	
	Product identification techniques – Electrophoresis, Thin layer chromatography, High performance liquid chromatography, gas chromatography.	1	
II	Distillation – Types of distillation – batch, continuous, industrial fractionation, extractive distillation, steam and vacuum distillation.	3	15%
	Extractive separations: General principles, analysis of batch and staged extraction - differential and fractional extraction-scale up and design of extractors - reciprocating plate extraction columns, centrifugal extractors- aqueous two phase extraction and supercritical fluid extraction – theoretical principles, process, equipment and applications.	4	
	FIRST INTERNAL EXAM		
	Adsorption: Adsorption equilibrium, adsorbent types, equipment operation- adsorption column dynamics- fixed bed and agitated bed adsorption, scale up of adsorption processes- LUB method	3	10%
III	Evaporation: Factors affecting evaporation, equipments – Number of effects, short tube, long tube, falling film evaporators.	2	25%
	Precipitation: Methods of precipitation, precipitate formation, Factors influencing protein solubility, design of precipitation systems	2	
	Product crystallization: Basic principles- nucleation and crystal growth - Mier's super saturation theory- kinetics of crystallization-analysis of dilution batch crystallization- commercial crystallizers- process crystallization of proteins, Recrystallization.	3	
	Product drying: Heat and mass transfer in drying- types of commercial dryers- vacuum dryers, freeze dryers, spray dryers- scale up and design of drying systems.	2	
SECOND INTERNAL EXAM			
IV	*Chromatographic separations*: Classification of techniques, elution chromatography- retention theory, band broadening effects, separation efficiency, resolution, yield and purity, discrete stage analysis, kinetic analysis- Gas and liquid chromatography- Bonded phase chromatography, Ion exchange chromatography, gel permeation chromatography, affinity chromatography- supercritical fluid chromatography - Chiral chromatography- expanded bed chromatography- simulated countercurrent chromatography- process scale up.	6	25%

	Electrokinetic separations: Electrophoresis – Principles and techniques.	1	
	Membrane separation processes: Cross flow filtration – filter media- ultra filtration and microfiltration membranes, filter modules, modes of operation, concentration polarization and fouling.	3	
	Equipments, principle and applications of reverse osmosis, dialysis, electrodialysis, pervaporation and perstraction.	1	
END SEMESTER EXAM			

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH6166	MODERN METHODS OF INSTRUMENTATION AND ANALYSIS	2-1-0-3	2015

Course Objectives

To familiarize the basic concepts of various modem instrumentation techniques used in chemical analysis

Syllabus

Working principle, components, areas of application of different types of Chromatography, spectroscopy, thermal analysis , microscopy and X-ray techniques.

Expected Outcome

The students completing this course will develop

- Acquaintance with modern instrumentation and analysis techniques
- Ability to describe the principles of analytical methods such as chromatography, spectroscopy, and thermal analysis, XRD, SEM ,AFM and TEM
- Ability to use modern instrumentation and classical techniques, to design experiments, and to properly record the results of their experiment

Reference Books

1. J. Mendham, J.D. Barnes, R.C. Denny& M.J.K.Tl1omas, Vogel's Textbook of Quantitative Analysis.
2. Gurdeep.R Chatwal ,Sham Anand ,Instrumental Methods of Chemical Analysis, Himalaya Publishing.
3. Hobart.H.Williard,Lynne.L.Merritt,John.A.Dan,Frank.A.Settle,Inst1umental Methods of Analysis,CBS Publishers & Distributors.

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Introduction to chemometrics- classification of instrumental techniques.	2	25%
	Basic functions of instrumentation-factors affecting choice of analytical method- interferences- data handling	3	
	Introduction to scanning electron microscopy, transform electron microscopy. Atomic force microscopy.	2	
	Introduction to differential scanning calorimetry(DSC), thermogravimetric analysis (TGA) and differential thermal analysis (DTA).	3	
II	Principles of chromatography.	1	12%
	Instrrmrentation of Gas liquid chromatography,-gas chromatography column, liquid phases and colurrm selection, detectors-thermal conductivity detectors, flame ionization detectors, thermionic emission detector and electron capture detector.	4	
	FIRST INTERNAL EXAM		
	HPLC instrumentation, mobile phase delivery system, sample introduction, Separation columns - standard column, narrow bore column, short fast column, guard	5	13%

	column and in-line filters, temperature control, detectors — UV visible photometers and spectrometers, electrochemical detectors. High pressure liquid chromatography-applications		
III	General feature of spectroscopy, interaction of radiation with matter.	1	25%
	Instrumentation of IR&FTIR spectroscopy, sample handling, quantitative analysis	4	
	NMR spectroscopy,-basic principles, spectra and molecular structure, elucidation of NMR spectra, quantitative analysis.	3	
	Mass spectroscopy- instrumentation ionization methods, mass analysis, correlation of mass spectra with molecular structure.	2	
SECOND INTERNAL EXAM			
IV	Introduction to XRD, production of X-ray and X-ray spectra. X-ray absorption methods	2	25%
	x-ray diffraction, and electron spectroscopy for chemical analysis	3	
	Surface area determination by BET method, particle size by light scattering method, zeta potential, colour etching spectrophotometer lavibond tintometer	4	
END SEMESTER EXAM			

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH6176	**COMPUTATIONAL FLUID DYNAMICS**	**2-1-0-3**	**2015**

Course Objectives

To build expertise in detailed study of Computational Flow Modelling, Solution of model equations and application in reactive flows and multiphase flows.

Syllabus

Introduction to computational modeling, index notation of vectors and tensors, control volume, Reynold's transport theorem, governing equations, phenomenological models, numerical methods for CFD, PDE's, properties of numerical solutions, accuracy and error, application of numerical methods, detailed study of Navier – Stokes equation, implicit and explicit methods, turbulence modeling, reactive flows and combustion, multiphase flow, polymeric liquids, rheological models, circulation, Die swell, extensional flows, DEM-Lattice Boltzmann-Immersed Boundary-Boundary Elements.

Expected Outcome

After successfully completing this course, the student will be able to

1. Develop an understanding of the major theories, approaches and methodologies used in CFD
2. Apply knowledge of basic science and engineering fundamentals to solve practical problems
3. Numerically solve the governing equations for fluid flow.
4. Understand grid generation, assess stability and conduct a grid convergence assessment.
5. Understand and apply turbulence models to engineering fluid flow problems.
6. Assess the quality of numerical results.
7. Understand the issues in multiphase flow modeling.

Text Books

1. Anderson, John David, Computational Fluid Dynamics: The Basics with Applications, McGraw Hill, 1995.

2. Anderson, D. A;Tarmeheil, J. C; Pletcher, R. H., Computational Fluid Mechanics and Heat transfer, Hernispher, New York, 1984.

3. Ferziger, J . H and Peric, M.,Computational methods for Fluid Mechanics, Springer, New York, 2002

4. Patankar, Suhas, V., Numerical Heat Transfer and Fluid Flow, McGraw Hill, Washington, 1980..

Reference Books

1. Smith, G. D., Numerical Solution ofPartial Differential Equations: Finite Diflference Methods, Claderon Press, Oxford.
2. Peyret, R.,Taylor, T. D. Computational Methods for Fluid Flow, Springer Verlag, 1983.
3. Ranade, V., Computational Flow Modelling for Chemical Reaction Engineering, Academic Press, 2002.
4. Bird, R. B., Armstrong, R. C., Hassagar,O. Hassagar, Dynamics of Polymeric Liquids, John Wiley, New York, 1987.

5. Barnes, H. A. ; Hutton, J. F. and K. Walters. An Introduction to Rheology Elsevier, 1993

6. Crowe, Clayton T. (Ed.) Multiphase flow handbook CRC Taylor 8: Francis, 2006

7. Bird, R. B; Stewart, W. E and Lightfoot, E. N, Transport Phenomena, John Wiley, New Delhi, 2002.

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Introduction to Computational Modeling of Flows - significance with special emphasis on chemical engineering applications. — Index notation of vectors and tensors-Control volume- Reynolds Transport Theorem-Governing equations— Non dimensional forms-Phenomenological models-boundary conditions-classification	9	25%
II	Numerical methods for CFD-classification of PDE's-Basic discretisation methods- Mesh- solution, and convergence-iterative methods-Properties of numerical solutions-accuracy and errors.	5	13%
	FIRST INTERNAL EXAM		
	Application of numerical methods to selected model equations such as wave equations- heat equation .Laplaces equation-Burgers equation-First and Second order methods such as upwind, Lax Wendroff, MacCormack methods etc.	5	12%
III	Detailed study of Navier stokes equation-Solution of the Navier Stokes equations-Discretization of convective, viscous, pressure and body force terms-conservation properties-grid arrangement-colocated and staggerd-pressure equation and its solutions—implicit and explicit methods-implicit pressure correction methods-Fractional Step method-SIIVIPLE algorithm for a colocated Variable arrangement Turbulence Modelling -The Turbulence Problern—Algebraic and Differential Models, k-ε models, Other Models	10	25%
SECOND INTERNAL EXAM			
IV	Reactive Flows and Combustion—Reactor Modelling (RTD Studies)-Polymerisation-Combustion Modelling—Multiphase Flow-Fluid/Fluid (bubbles/drops)-Fluid/Solid (fluidised beds, pneumatic conveying, settling) -Polymeric Liquids-Rheological models-Special cases: Circulation, Die- swell, Extensional flows-Brief Introduction to Other Approaches -CFD—DEM-Lattice Boltzmann-Immersed Boundary-Boundary Elements.	10	25%
END SEMESTER EXAM			

Course No	Course Name	L-T-P- Credits	Year of Introduction
09CH6186	**INDUSTRIAL POLLUTION CONTROL**	**2-1-0-3**	**2015**

Course Objectives:

- To impart the basic concepts of industrial pollution control
- To develop understanding about water, air, Soil pollution control

Syllabus:

Water pollution laws and standards - industrial wastewater treatment, processes and equipment. Water pollution control in different Chemical industries, Air Pollution Laws, Air pollutants monitoring equipment and method of analysis, Air pollution control methods in industries, sludge treatment and disposal.

Expected Outcome:

1. To understand the needs of environmental pollution control.
2. Apply the Air, Water and Environmental (Protection) Act, Hazardous and Solid Waste (Management & Handling) rules for prevention and control of pollution.
3. Analyze the emission of pollutants from industries and its health effects.
4. Design proper control methods to prevent pollution through air, water and sand.
5. Design Effluent Treatment plant based on effluent characteristics.

Text Books:

1. Rao M.N. & Rao H,Air Pollution, Tata Mcgraw Hill
2. Mahajan S.P., Pollution Control In Process Industries, Tata Mcgraw Hill
3. Mccaff & Eddy , Waste Water Treatment
4. Peavy , Environmental Engineering
5. Rao C.S., Environmental Pollution Control Engineering, New Age Int. Pub.
6. Gerard Kiely, Environmental Engineering, Mcgraw Hill

Reference Books:

1. Nelson & Nemerow, Industrial Water Pollution-Origin, Characteristics And Treatment, Addison, Wesley Publishing Co.
2. Sincero A.P.& Sincero G.A., Environmental Engineering, A Design Approach, Prentice Hall Of India
3. Babbitt H.E, Sewage & Sewage Treatment, John Wiley
4. Abbasi S.A, & Ramasami E, Biotechnical Methods Of Pollution Control, Universities Press (India) Ltd.
5. S C. Bhatia, Handbook of industrial pollution control vol-1 and 2.

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Classification of industrial wastewater	1	25%
	Types of pollutants and their effects	1	
	Monitoring and analysis Methods	2	
	Water pollution laws and standards	1	
	Industrial wastewater treatment - processes	2	
	Industrial wastewater treatment -equipment.	2	

II	Water pollution control in industries -- Pulp and paper, Textile processing Tannery wastes, Dairy wastes Cannery wastes, Brewery Distillery, Meet Packing, Food Processing Wastes Pharmaceutical wastes, Chlor -Alkali Industries	 1 1 1 1 1	12%
	FIRST INTERNAL EXAM		
	Fertilizer Industry Petrochemical Industry Rubber Processing Industry, Starch Industries Metal Industries, Nuclear Power Plant Wastes Thermal Power Plant Wastes.	1 1 1 1 1	13%
III	Air pollution control in industries: source and classification of industrial air pollutant Monitoring equipment and method of analysis Damages to health, vegetation and Materials Air pollution laws and standards **Treatment method in specific industries** - thermal power plants - cement Fertilizers - Petroleum Refineries Iron and steel - chlor-alkali Pulp and paper.	2 1 1 1 2 1 1 1	25 %
SECOND INTERNAL EXAM			
IV	Industrial odour control - sources and solutions - odour control by adsorption and wet scrubbing Industrial noise control methods Sludge treatment and disposal Industrial hazardous waste management, Waste minimization. Environmental Impact Assessment and risk assessment-Environmental Audit and Environmental management system Concept of common effluent treatment plants.	2 1 1 2 2 2	25%
END SEMESTER EXAM			

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH6196	**ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS**	**2-1-0-3**	**2015**

Course Objectives

The students completing this course will develop

1. The ability to apply energy and entropy balance to practical situations
2. In-depth understanding of phase and reaction equilibria.
3. A general approach for establishing the conditions for equilibrium and stability for complex systems
4. The capability of working with multi-phase pure materials and mixtures.
5. The skill to solve problems involving phase equilibrium of single and multi component systems
6. The ability to apply the knowledge of thermodynamics to design problems.

Syllabus

Basic concepts of thermodynamics, thermodynamic properties of fluids, properties of solutions, phase equilibria for single component and multi component systems, reaction equilibrium.

Expected Outcome

Students will be able to

1. Understand the importance and relevance of thermodynamics in life processes
2. Analyze various situations and apply the concepts of thermodynamics to problem solving.
3. Work with single and multiphase systems of pure materials and mixtures.
4. Apply the knowledge of thermodynamics to design problems.

Text Books

1. Smith J. M. & Van Ness H.V., Introduction to Chemical Engineering Thermodynamics, McGraw Hill
2. Narayanan K. V., A Textbook of Chemical Engineering Thermodynamics, Prentice-Hall of India

Reference Books

1. Kyle B.G., Chemical and Process Thermodynamics, Prentice-Hall of India
2. Y.V.C. Rao, Chemical Engineering Thermodynamics, Universities Press
3. Stanley I. Sandler. Chemical Engineering Thermodynamics, John Wiley & Sons
4. M. D. Koretsky. Engineering and Chemical Thermodynamics, John Wiley & sons.
5. Hougen A., Watson K.M. & Ragatz R.A., Chemical Process Principles Vol.2, Asia Pub.
6. K.V.Narayanan & B.Lakshmikutty. Stoichiometry and Process Calculations, Prentice Hall of India

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Basic concepts – internal energy, enthalpy, entropy, work, ideal and real gas laws.	3	25%
	Thermodynamic properties of pure fluids - Gibbs free energy, work function - Maxwell’s equations - Clapeyron equation , Joule-Thomson coefficient - Gibbs - Helmholtz equation.	3	

	Fugacity and activity of pure fluids - effect of temperature and pressure on fugacity and activity.	3	
II	Properties of solutions, partial molar properties, chemical potential, fugacity in solutions, Lewis-Randall rule	3	13 %
	Henry's law, ideal solutions - Raoult's law, activity in solutions, Gibbs-Duhem equations, excess properties.	4	
	FIRST INTERNAL EXAM		
	Phase equilibria in single component and multi component systems, phase rule for non-reacting systems - Duhem's theorem	3	12 %
III	VLE in ideal solutions - non-ideal solutions - positive and negative deviation - azeotropes	3	25 %
	VLE at low pressures - Wohl's equation - van Laar equation – Wilson equation - application of activity coefficient equations in equilibrium calculations - basic idea on NRTL, UNIQUAC and UNIFAC methods	2	
	Phase equilibrium - vapour-liquid equilibrium at high pressures, bubble point, dew point and flash calculations in multi component systems - computer programs for these calculations	2	
	Consistency tests for equilibrium data, calculation of activity coefficients using Gibbs - Duhem equations	2	
	Vapour-liquid equilibrium in partially miscible and immiscible systems, phase diagrams - liquid-liquid equilibrium - binary and ternary equilibrium diagrams.	2	
SECOND INTERNAL EXAM			
IV	Chemical reaction equilibria - criteria of chemical equilibrium - equilibrium constant, Feasibility of reaction, factors affecting equilibrium conversion	5	25%
	Phase-rule for reacting systems. Heterogeneous chemical reactions, combined chemical and phase equilibrium.	4	
END SEMESTER EXAM			

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH6162	**MINIPROJECT**	**0-0-4-2**	**2015**

Course Objectives

- To practice the steps involved for the selection, execution, and reporting of the project.
- To train the students for group activities to accomplish an engineering task.

Student group consist of maximum of 2 members are required to choose a topic of their interest. The subject content of the mini project shall be from emerging / thrust areas, topics of current relevance having research aspects or shall be based on industrial visits. At the end of the semester, the students should submit a report duly authenticated by the respective guide, to the head of the department.

Evaluation will be conducted by a committee consisting of three faculty members. The students are required to bring the report completed in all respects duly authenticated by the respective guide and head of the department, before the committee. Students individually will present their work before the committee. The committee will evaluate the students individually and marks shall be awarded as follows.

Mini Project will have internal marks100.

Attendance & Regularity	:10+10 marks
Evaluation I	: 30 marks
Evaluation II	: 30 marks
Assessment by Guide	: 20 marks

Expected Outcome

At the end of the course the student will be able to

1. Implement the methods/techniques identified
2. Analyse and interpret the results obtained.
3. Prepare a report that includes information on a topic

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH6172	**DESIGN, SIMULATION AND INSTRUMENTAL - ANALYSIS LAB**	**0-0-2-1**	**2015**

Course Objectives

To provide the students with the fundamental knowledge of

- Programming and computation in MATLAB.
- Design of processes and equipments and their simulation using softwares.
- Measurement and analysis of process variables by using modern instruments.

Optimal design of the following.

1. Distillation column for binary mixture: plate & packed columns, Multi- component distillation. Absorption tower both plate as well as packed type.

2. Liquid —liquid extraction columns: mixer-settler, packed columns. Design of dryers: Rotary dryer, Tray dryer.

3. Multiple Effect Evaporators.

List of experiments in Instrumental Analysis Lab

1. UV-Visible spectrophotometer
2. Infrared spectrophotometer
3. Atomic absorption spectrophotometer.
4. Flame photometer
5. Thermo gravimetric analyzer
6. Differential scanning calorimeter
7. Differential thermal analyzer
8. Gas chromatograph.
9. High performance liquid chromatograph

Intemal Continuous Assessment (MaximumMarks-100):

Regularity	:30marks
Record	:20marks
Tests, Viva	:50marks

Expected Outcome

At the end of the course the student will be able to

1. Solve complex chemical engineering problems by applying suitable numerical methods.
2. Design the process equipment using software.
3. Analyse different parameters using Modern instruments

THIRD SEMESTER

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH7117	PROCESS INTEGRATION	2-1-0-3	2015

Course Objectives

The students completing this course will develop

1. The ability to analyse heat exchanger networks
2. The ability to find out the energy requirement for a process using composite and grand composite curves
3. The ability to do Thermodynamic analysis (Pinch analysis), design and optimization of energy efficient industrial processes
4. The ability to modify processes for minimisation of raw material and waste generation

Syllabus

Introduction to Process Integration- Heat Exchanger Networking – Graphical representation of heat utilisation-Reactor Integration - . Reactor configurations: Temperature Control, Gas-Liquid and Liquid-Liquid Reactors- Distillation Integration- various configurations for heat integration of distillation column.- Mass Exchanger Network Synthesis

Expected Outcome

The students completing this course will develop the skills

1. To design heat exchanger with minimum external heating/cooling with fewest number of units and lowest possible total area in the heat exchanger
2. To suggest energy optimal integration solutions for distillation columns, evaporators heat and power systems
3. To do mathematical optimization within process design

Text Books

1. Chemical Process Design and Integration Robin Smith, John Wiley and Sons. Ltd., New Delhi,

2005.

Reference Books

1. Product 8: Process Design Principles Warren D. Seider, J . D. Seader and Daniel R. Lewin, Wiley Publication. 3. Heat Exchanger Network Synthesis U. V. Shenoy, Gulf Publication

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Introduction to Process Integration- Importance of Process Integration and applications in Chemical Industries. Overview of Process Integration. Heat Exchanger Networking-Hot Composite Curve, Cold Composite Curve, Problem Table Algorithm, Grand Composite Curve, Area Targeting by Uniform Bath formula and Unit Targeting by Eulers' formula, Heuristics for Pinch Design, Maximum Energy Recovery Design, Evolution of	9	25%

	Network.		
II	Reactor Integration-Choice of Idealized reactor model and reactor performance. Reactor configurations: Temperature Control, Gas-Liquid and Liquid-Liquid Reactors, Choice of Reactors	5	13%
	FIRST INTERNAL EXAM		
	Heat Integration characteristics of reactors, Appropriate placements of reactors. Use of GCC for Heat Integration of reactors.	5	12%
III	Distillation Integration-Distillation sequencing, Heat Integration characteristics of Distillation column, appropriate placement of distillation column, various configurations for heat integration of distillation column.	10	25%
SECOND INTERNAL EXAM			
IV	Mass Exchanger Network Syntlresis-Mass Exchanger Network, Minimum Mass Separating Agents (MSA), Mass exchange networks for minimum external MSA. Minimum Number of Mass Exchangers.	10	25%
END SEMESTER EXAM			

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH7127	**NON-CONVENTIONAL ENERGY SOURCES**	**2-1-0-3**	**2015**

Syllabus

Non—conventional energy sources, Nuclear Energy, Solar Energy Utilisation (Thermal), Energy from Ocean, Wind, Tides and geothermal sources, Energy from biomass

Expected Outcome

Understand of nuclear energy and nuclear fission principles

Understand solar Energy sources

Understand wind Energy conversion systems

Understand energy from biomass biomass utilization

Text Books

1. Goldmberg J., Johansson, Reddy A.K.N. & Williams R.H., Energy for a Sustainable ,World, John Wiley
2. Bansal N.K., Kleeman M. & Meliss M., Renewable Energy Sources & Conversion Tech., Tata McGraw Hill
3. Sukhatme S.P., Solar Energy, Tata McGraw Hill
4. Mittal K.M., Non-Conventional Energy Systems, Wheeler Pub.
5. Pandey G.N., A Text Book on Energy System and Engineering, Vikas Pub.
6. Rai G.D., Non-Conventional Energy Sources, Khanna Pub.

Reference Books

1. Venkataswarlu D., Chemical Technology, I, S. Chand
2. Rao S. & Parulekar B.B., Energy Technology, Khanna Pub.

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Nuclear Energy: Nuclear fission principles, types of nuclear reactors (BWR, PWR, PHWR, LMCR, GCR, FFR). Nuclear reactor analysis: four factor formula, resonance absorption, reactor buckling, multiplication factor, thermal utilisation coefficient, reflector saving, fast fission factor, optimum moderator to fuel ratio. Radioactive waste disposal.	9	25%
II	Solar Energy Utilisation (Thermal): Construction and performance analysis of solar flat plate collectors. Heat losses from FPC by radiation and natural convection, overall heat loss coefficient, collector efficiency factor, tilt factors, collector heat removal factor, Hottel-Willier- Bliss equation.	5	13%
	FIRST INTERNAL EXAM		
	Solar concentrating collectors : CPC, PTC, spherical parabolic aids , modes of tracking, performance analysis. Salt gradient solar ponds: construction, operation, technical problems. Solar drying and dehumidification: Solar cabinet dryers, convective dryers.	5	12%
1II	Energy from Ocean, Wind, Tides and geothermal sources: OTEC power plants (closed cycle, open cycle, hybrid	10	25%

	cycle), operation and technical problems, environmental impact. Tidal power, salinity power plants. Wind energy: Design and analysis of wind turbines. Geothermal systems : Hot water and dry steam systems, energy extraction principles.		
SECOND INTERNAL EXAM			
IV	Energy from biomass**:** Biomass utilisation : pyrolysis, gasification, anaerobic digestion (biogas production). Biodiesels : Manufacture and characteristics. Gasohol : Characteristics and manufacture , use of pervaporation technology. Synthetic liquid fuels from coal: F — T Process, Coal hydrogenation, MTOG process.	10	25%
END SEMESTER EXAM			

Course No	Course Name	L-T-P- Credits	Year of Introduction
09CH7137	**ADVANCED BIOPROCESS ENGINEERING**	**2-1-0-3**	**2015**

Course Objectives

To familiarize the students with various advanced theories in bioprocess engineering and kinetic parameters.

Syllabus

Introduction to fermentation process, Stoichiometry of microbial growth and product formation, Classification of microbial products, Material balance and energy balance of bioprocesses, Mass transfer in bioprocessing systems, Scale up and scale down of bioprocess systems, Design of novel bioreactors

Expected Outcome

The course will enable the student to:

1.Build mathematical models of microbial growth and product formation

2.Design a biological product and the desired bioprocess

3.Select or design appropriate bioreactor model based on the bioproduct and microbial strain

4.Develop suitable bioproduct separation techniques

5.Design proper bioprocess waste treatment methods

Text Books

1. M.L. Shuler and F. Kargi, "Bioprocess engineering", 2nd Edition, Prentice Hall of India, New Delhi. 2002.
2. J. E. Bailey and D.F. Ollis, "Biochemical Engineering Fundamentals", 2nd Ed., McGraw-Hill Publishing Co. New York. 1986.
3. P. Stanbury, A. Whitakar and S. J. Hall, "Principles of Fermentation Technology" 2nd Ed., Elsevier-Pergamon Press, 1999.

Reference Books

1. Karl Schugerl, Bioreaction Engineering (Volume 1), John Wiley, 1987.
2. Pauline Doran, Bioprocess Engineering Calculation, Academic Press, 1995.

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Introduction: Fermentation processes,General requirements of fermentation processes, An overview of aerobic and anaerobic fermentation processes and their application in industry, Medium requirements for fermentation processes - examples of simple and complex media. Stoichiometry of microbial growth and product formation: Growth stoichiometry and elemental balances, Respiratory	9	25%

	quotient, Degree of reduction, Yield and maintenance coefficients, Oxygen consumption in aerobic microbial cultures, Theoretical Oxygen demand- problems.		
II	Classification of microbial products - Growth associated, Non-growth associated and Mixed growth associated product formation. Material balance and energy balance: Material balance for industrial fermentation, Downstream processing and waste treatment processes- problems.	5	13%
	FIRST INTERNAL EXAM		
	Energy balance for fermentation and downstream processing, Thermodynamics of microbial growth, Heat generation in microbial cultures-problems	5	12%
III	Mass transfer in bioprocessing systems: Oxygen transfer mechanism, Assessment of K_La- chemical method, dynamic differential gassing out method, dynamic integral gassing out method, oxygen balance method, enzymatic method- merits and demerits of each method. Scale up and scale down of bioprocess systems: Need for scale up and scale down, Operating boundaries for aerated and agitated fermenters, Scale up criteria for microbial cell processes- constant power input per unit volume, constant K_La, constant mixing quality, constant momentum factor, constant impeller tip speed, constant mixing rate number, Scale down procedure	10	25%
SECOND INTERNAL EXAM			
IV	Design of novel bioreactors- Packed bed bioreactors, Bubble-column bioreactors, Fluidized bed bioreactors, Trickle bed bioreactors, Airlift loop bioreactors, Photobioreactors. Thermal death kinetics of cells and spores: Survival curve, Decimal reduction factor, Extinction probability, Sterilization of culture medium, Batch and continuous sterilization- design aspects, Air sterilization, Design of fibrous type filters.	10	25%
END SEMESTER EXAM			

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH7147	**MATHEMATICAL METHODS IN CHEMICAL ENGINEERING**	**2-1-0-3**	**2015**

Course Objectives

The students completing this course will be able to

1. To solve problems of algebraic, differential , simultaneous and partial differential equations
2. Formulate mathematical model using single and multivariable calculus to enable engineering solutions to practical problem
3. Apply pure mathematics content to problems related to practical Chemical Engineering
4. Assess reasonableness of solutions and select appropriate levels of solution sophistication

Syllabus

Mathematical formulation of the physical problems- Analytical solution of ordinary differential equations encountered in chemical engineering problems- The difference operator- Application of statistical methods

Expected Outcome

The students completing this course will be able to evaluate a mathematical solution in terms of the original path

Text Books

1. Jenson, V.J. and Jeffereys, G.V., Mathematical Methods in Chemical Engineering, Academic Press, London and New York, 1977.
2. S. Pushpavanam, Mathematical Methods in Chemical Engineering, PHI.

Reference Books

1. Mickley, H.S., Thomas. K. Sherwood and Road, C.E., Applied Mathematics in Chemical Engineering, Tata McGraw-Hill Publications, 1957.

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Mathematical formulation of the physical problems - application of the law of conservation of mass, salt accumulation in stirred tank, starting equilibrium still, solvent extraction in two stages, diffusion with chemical reaction, application of the law of conservation of energy, radial heat transfer through cylindrical conductors, heating a closed kettle, flow of heat from a fin.	9	25%
II	Analytical (explicit) solution of ordinary differential equations encountered in chemical engineering problems first order differential equations, method of separation of variables,	3	8%
	FIRST INTERNAL EXAM		
	Equations solved by integration factors Examples involving mass and energy balances and reaction kinetics, second order differential equations, non-linear equations, linear equations, simultaneous diffusions and chemical	7	17%

	reaction in a tubular reactor. Formulation of partial differential equations, unsteady state heat conduction in one dimension, mass transfer with axial symmetry.		
III	The difference operator, properties of the difference operator, difference tables and other difference operators, linear finite difference equations, the complimentary solution of the particular solution, simultaneous linear differential equations, non-linear finite difference equations, analytical solution. Solution of the following type of problems by finite difference method - calculation of the number of plates required for absorption column, calculation of the number of theoretical plates required for distillation column, number of steps required for a counter-current extraction and leaching operations.	10	25%
SECOND INTERNAL EXAM			
IV	Application of statistical methods - propagation of errors of experimental data, parameter estimation of algebraic equations encountered in heat and mass transfer, kinetics and thermodynamics by: the method of averages, linear least squares and weighted line	10	25%
END SEMESTER EXAM			

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH7167	**ADVANCED PROCESS CONTROL**	**2-1-0-3**	**2015**

Course Objectives

The students completing this course will learn

1. The concepts of linear feedback control theory
2. Recent developments in control theory
3. Selection and applicability of different modes of controllers
4. To analyze the stability of systems and design controllers for robustness
5. Digital control
6. To simulate control systems using software

Syllabus

Basics of linear open loop and closed loop systems, different modes of controllers, performance criteria, stability analysis, advanced control strategies, sampled data control systems.

Text Books

1. D.R. Coughanour 'Process Systems analysis and Control', , McGraw-Hill, 2"' Edition,1991.
2. Stephanopoulous, 'Chemical Process Control — Theory and Practice', Prentice Hall of India Ltd.,1984
3. E. Seborg, T.F. Edger, and D.A. Millichamp 'Process Dynamics and Control',John Wiley and Sons, 2nd Edition, 2004.

Reference Books

1. C.A. Smith and A.B. Corripio. 'Principle and Practice of Automatic Process Control', 3" ed., John Wiley and Sons, 2005.
2. W.L .Luyben 'Process Modelling Simulation and Control for ChemicalEngineers,McGraw Hill, 2nd Edition,1990.
3. Ogunnaike B. A. and Ray W. H., "Process Dynamics Modeling and Control", Oxford University Press
4. Bequette B. W., "Process Control – Modeling, Design and Simulation", Prentice-Hall of India.

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Introduction to linear open and closed loop	2	25%
	Different modes of controllers- P, PI, PID.	2	
	Performance criteria of controllers — the error performance indexes	2	
	Systems Control valves — characteristics, sizing and valve positioners.	2	
	Introduction to PLC, SCADA, DCS systems	2	

II	Stability Analysis: Frequency response analysis, Bode plots	3	12 %
	Nyquist plots	1	
	FIRST INTERNAL EXAM		
	Process identification.	1	13 %
	Controller tuning - Zigler-Nichols and Cohen-Coon tuning methods	3	
	Relay tuning.	1	
III	Special Control Techniques: Advanced control techniques, cascade, ratio, feed forward controls	3	25 %
	Aadaptive control, selective controls	2	
	Computing relays, simple alarms	1	
	Smith predictor	1	
	Internal model control.	3	
SECOND INTERNAL EXAM			
IV	Sample Data Controllers: Basic review of Z transforms	3	25%
	Response of discrete systems to various inputs. Open and closed loop response to step, impulse inputs,	4	
	Closed loop response of discrete systems.	3	
END SEMESTER EXAM			

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH7177	**NANOMATERIALS AND NANOTECHNOLOGY**	**2-1-0-3**	**2015**

Course Objectives

The students completing this course will develop

1. Understanding on nanotechnology and different types of nanomaterials.
2. Knowledge of synthesis and characterization of various nanomaterials such as nanoparticles, nanocomposites, etc.
3. Familiarity with the sophisticated analytical tools used for imaging, characterization and manipulation of nanomaterials.

Syllabus

Introduction to nanotechnology. Synthesis and characterization of nanomaterials. Nanocomposites and smart materials. Nanomanipulation.

Expected Outcome

Students should get familiarized with aspects of nanotechnology, their applications and the ongoing research in this area.

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Introduction to nanotechnology, nanoscale, electromagnetic spectrum, top down and bottom up approach, particle size, chemistry and physics of nanomaterials, electronic phenomenon in nanostructures, optical absorption in solids, quantum effects.	9	25%
II	Nanomaterials, preparation of nanomaterials like gold, silver, different types of nano-oxides, A1203, TiO2, ZnO etc. Sol-gel methods, cherrrical vapour deposition, ball milling etc.	5	13%
	FIRST INTERNAL EXAM		
	Carbon nanotubes, preparation properties and applications like field emission displays. Different types of characterization techniques like SEM, AFM, TEM & STM.	5	12%
III	Nanocomposites, nanofillers, high performance materials, polymer nanocomposites, nanoclays, nanowires, nanotubes, nanoclusters etc. Smart materials, self assembly of materials, safety issues with nanoscale powders.	10	25%
	SECOND INTERNAL EXAM		
IV	Nanomanipulation, Micro and nanofabrication techniques, Photolithography, E-beam, FIB etc. Nanolithography, softlithography, photoresist materials. Introduction to MEMS, NEMS and nanoelectronics. Introduction to bionanotechnology and nanomedicines.	10	25%
	END SEMESTER EXAM		

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH7187	**SEPARATION PROCESSES**	**2-1-0-3**	**2015**

Course Objectives

The students are familiarized with the concepts of advanced separation processes like Membrane separation processes, diffusional separation process, multicomponent absorption, azeotropic and extractive distillation.

Syllabus

Fundamentals of Separation Processes; basic definitions of relevant terms. Membrane based separation processes; fundamentals and various terms; classifications. Diffusional separation processes; gaseous diffusion, mechanism, process description, design considerations, basic principles. Introduction to multicomponent absorption, azeotropic distillation, extractive distillation.

Expected Outcome

- Knowledge of various chemical engineering separation processes
- Ability to select appropriate separation technique for intended problem
- Ability to analyze the separation system for multi-component mixtures
- Ability to design separation system for the effective solution of intended problem

Text Books

1. Seader, Henly, Separation process principles, John Wiley
2. Shoen K.M, New chemical engineering separation techniques, Inter Science (1962).
3. Loeb. S, Industrial membrane separation processes.
4. Winkle M.W, Distillation, McGraw Hill.
5. Sherwood T.K, R.L Pigford and C.R Wilke, Mass transfer, McGraw Hill
6. McCabe W.L, J.C .Smith and P. Harriot, Unit operations in chemical engineering, McGraw Hill.

Reference Books

1. Perry. J.H and C.E. Chilto, Chemical engineer's handbook, McGraw Hill
2. Rousseau R.W, Handbook of separation process technology, John Wiley (1987).

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Membrane separation processes — fundamentals, mechanism and equilibrium relationships, types and structure of membranes, membrane permeation of liquids and gases, effects of concentration, pressure and temperature, dialysis: mechanism, basic idea on dialyser design, industrial application, reverse osmosis, definitions and theory, design considerations, applications, ultra filtration.	10	25%
II	Diffusional separation processes — gaseous diffusion, mechanism, process description, design considerations, basic principles.	5	13%
	FIRST INTERNAL EXAM		
	Diffusional separation processes- application, equipment	4	12%

	for thermal diffusion and pressure diffusion.		
III	Azeotropic and extractive fractional distillation — separation of homogeneous azeotropes, separation of heterogeneous azeotropes, quantitative treatment of separation of binary heterogeneous azeotropes, selection of addition agents, selectivity, factors affecting selectivity, methods for prediction, mechanism of relative volatility change, choice of entrainer or solvent, design of an azeotropic distillation process, design of an extractive distillation process, methods of solvent recovery.	10	25%
SECOND INTERNAL EXAM			
IV	Absorption of gases — non isothermal operation, adiabatic absorption and stripping in packed columns, multicomponent absorption, graphical and algebraic method for multistage operation, multicomponent mass transfer effects in the design of packed columns.	10	25%
END SEMESTER EXAM			

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH7197	**POLYMER COMPOSITES**	**2-1-0-3**	**2015**

Syllabus

Introduction to composite materials, Manufacturing of advanced composites, Theory of reinforcement, Testing of composites

Expected Outcome

- Be familiar with a range of composite types, their production and commercial applications of composites.
- Understand mechanical behaviour of composites and the theoretical background.
- Understand the underlying principals of polymer structure-properties relationships.
- Understand design principles for the manufacture of polymer-based products.
- Understand testing of composite material and quality control methods

Text Books

1. Polymer Engineering Composites. Ed.M.O.W. Richardson, Applied Science Publishers, London.
2. Composite Materials – K.K.Chawla
3. An Introduction to Composite Materials, D. Hull, Cambridge University Press, Cambridge.

Reference Books

1. Handbook of composites- G.Lubin, Von Nostrand, New York, 1982.
2. Mohr.J.G.et al, SPI handbook of Technology and Engineering of reinforced Plastics/Composites, Von Nostrand, New York.
3. Katz.H.S. & J.V. Milewski, Handbook of Fillers and Reinforcement for plastics- Von Nostrand, New York.

Course Plan

Module	Contents	Hours	Semester exam marks %
I	Introduction to composite materials-definitions - classification based on structure- types of composite materials-plastics matrix composites-rubber matrix composites-metal matrix composites-ceramic and other brittle matrix composites. Characteristic features and advantages of composites materials- reinforcement and matrix materials and their properties. FRP - Reinforcement fibre- Glass, carbon, Kevlar, boron, asbestos, steel, natural fibre and whiskers, surface treatment for fibre-size and coupling agents. Commonly used fibre and additives in FRP and their effects-various types of resins used – polyester resins-epoxy and phenol formaldehyde resins.	9	25%

II	Manufacturing of advanced composites: Polymer matrix composites: Preparation of Moulding compounds and prepregs – hand lay up method – Autoclave method – Filament winding method – Compression moulding – Reaction injection moulding- vacuum bag moulding centrifugal casting-pultrusion-machinery, operation, advantages and disadvantages -	5	13%
	FIRST INTERNAL EXAM		
	Fibre Reinforced Thermoplastics(FRTP) preparation-brief description of coating process melt compounding process and dry blending process-injection moulding, rotational moulding and cold forming of reinforced thermoplastics.	5	12%
III	Theory of reinforcement – selection of matrix and reinforcement-mechanics of composite materials-micromechanics and macro mechanics, mechanism of load transfer-minimum and critical fibre content-critical fibre length-law of mixture rule-unidirectional and fibrous composites-effects of fibre orientation on stiffness and strength-bidirectional and random fibre composites-concepts of unit cell-stress analysis of unit cells-toughness of fibrous composites, microscopic stress-strain curves.	10	25%
SECOND INTERNAL EXAM			
IV	Testing of composites materials and products for quality control- Brief outlines of testing of glass fibre, testing of resins-testing of products. General design considerations-design values factor of safety-working stress approach – service ability design-warning of danger-design process-shape design & selection of materials and processing methods-application of composite of materials in various fields-chemical industries- electrical and electronic industries- aerospace, marine, and transport applications-application in buildings.	10	25%
END SEMESTER EXAM			

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH7163	**SEMINAR**	**0-0-2-2**	**2015**

Course Objectives

To assess the debating capability of the student to present a technical topic. Also to impart training to a student to face audience and present his/her ideas and thus creating self esteem and courage that are essential for an engineer.

Individual students are required to choose a topic of their interest from process design/design related topics preferably from outside the M.Tech syllabus and give a seminar on that topic about 45 minutes. A committee consisting of at least three faculty members shall assess the presentation of the seminar and award marks to the students based on merits of topic of presentation. Each student shall submit two copies of a write up of the seminar topic. One copy shall be returned to the student after duly certifying it by the chairman of the assessing committee and the other will be kept in the departmental library. Internal continuous assessment marks are awarded based on the relevance of the topic, presentation skill, quality of the report and participation.

Internal Continuous Assessment *(Maximum Marks-100)*

Relevance + Literature	: 10 marks
Concept / Knowledge in the topic	: 20 marks
Presentation	: 40 marks
Report	: 30 marks
Total marks	**: 100 marks**

Expected Outcome

At the end of the course the student will be able to

3. Communicate with group of people on different topics
4. Prepare a Seminar report that includes consolidated information on a topic

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH7183	PROJECT (PHASE - I)	0-0-12-6	2015

Course Objectives

To improve the professional competency and research aptitude by touching the areas which otherwise not covered by theory or laboratory classes. The project work aims to develop the work practice in students to apply theoretical and practical tools/techniques to solve real life problems related to industry and current research.

The project work can be a design project which contains design of part of the plant] experimental project and or computer simulation project on chemical engineering or any of the topics related with chemical engineering stream. The project work is allotted individually on different topics. The students shall be encouraged to do their project work in the parent institute itself. If it is found essential, they may be permitted to continue their project outside the parent institute subject to the conditions in clause 10 of M.Tech regulations. Department will constitute an Evaluation Committee to review the project work. The Evaluation committee consists of at least three faculty members of which internal guide and another expert in the specified area of the project shall be two essential members.

The student is required to undertake the project phase-I during the third semester. Phase-I consists of preliminary thesis work, two reviews of the work and the submission of preliminary report. First review would highlight the topic, objectives, methodology and expected results.

Supervisor	: 20 marks
Committee	: 30 marks
Total	**:50marks**

Expected Outcome

At the end of the course the student will be able to

1. Implement the methods/techniques identified
2. Analyse and interpret the results obtained.
3. Compare the result obtained with literature
4. Demonstrate the original contribution to knowledge

FOURTH SEMESTER

Course No	Course Name	L-T-P-Credits	Year of Introduction
09CH7184	**PROJECT (PHASE - II)**	**0-0-21-12**	**2015**

Course Objectives

To improve the professional competency and research aptitude by touching the areas which otherwise not covered by theory or laboratory classes. The project work aims to develop the work practice in students to apply theoretical and practical tools/techniques to solve real life problems related to industry and current research.

The third semester project is continued in the 4th semester (Phase—II). Second review evaluates the progress of the work, preliminary report and scope of the work which is to be completed in the 4th semester.

Supervisor	: 30 marks
External	: 30 marks
Committee	: 40 marks
Total	**: 100 marks**

Expected Outcome

At the end of the course the student will be able to

1. Implement the methods/techniques identified
2. Analyse and interpret the results obtained.
3. Compare the result obtained with literature
4. Demonstrate the original contribution to knowledge