Jharkhand University of Technology Ranchi

Course Structure & Syllabus

Master of Technology in Plant Design

Department of Chemical Engineering

December 2021

(With effect from Academic Year 2021-22)

LIST OF CONTENTS

StructureofM.Tech.

(The course structure is as per the Clause 6 mentioned in the JUT Academic Ordinances for M.Tech.Programme with effect from Academic Year 2021-22).

(Totalcredits = 68)

1st Sem:(*Totalnumber of credits=21*)

2 Core Subjects	2*3	=	6 Credits
3Programme Electives	3*3	=	9 Credits
1 Compulsory Course	1*2	=	2 Credits
2 Labs	2*2	=	4 Credits
1 Audit Course			None credit

2nd Sem:(*Total numberof credits=21*)

2 Core Subjects	2*3	=	6 Credits
2 Programme Electives	2*3	=	6 Credits
1 Open Elective	1*3	=	3 Credits
1 Compulsory MinorProject	1*2	=	2 Credits
2 Labs	2*2	=	4 Credits
1 Audit Course			None credit

3rd Sem:(*Totalnumberof credits=10*)

Dissertation Phase I	=	10Credits

4th Sem:(*Totalnumberof credits= 16*)

Dissertation Phase II	=	16Credits

Examinations and Assessment Method

(This is as per the Clause 10 mentioned in the JUT Academic Ordinances for M.TechProgrammes with effect from Academic Year 2021-22).

1. In each semester, the theory marks of each subject shall be distributed as follows-

End Semester Examination	**60 Marks**
Internal Assessment	**40 Marks**

2. Internal Assessment in respect of Theory marks of each subject in each semester shall be distributed as follows-

Internal Assessment	Marks
Mid Semester Exam	20
Class Test, Quizzes and Assignment	20
Total	40

3. Practical/ Viva Voce Examination marks shall be distributed as follows-

Internal Assessment	Marks
Viva Voce examination by External examiner	20
Practical performed during the examination	30
Lab record/ Performance in practical during the semester	50
Total	100

4. Presentation at the end of Third Semester 100 marks

5. Final presentation on the Dissertation at the end of the Fourth Semester-

Evaluation	Marks
External examiner	60
Supervisor(s)	100
Other committee members	40
Total	200

6. Method of Converting percentage marks to grades

Percentage of Marks Obtained	Letter Grade	Grade Point
90% and above	A+	10
80% to less than 90%	A	9
70% to less than 80%	B+	8
60% to less than 70%	B	7
50% to less than 60%	C+	6
40% to less than 50%	C	5
Less than 40%	F	0
Failed due to shortage of attendance	I	0

Course Structure

Course Structure M. Tech. (Plant Design)
Academic Session 2021-22 onwards
SEMESTER I

S. No.	Course Code	Course	Subject	L	T	P	Cr.
1.	PD 1101	Core - I	Chemical Engineering Analysis: Application of Mathematical & Statistical Methods	3	0	-	3
2.	PD 1102	Core - II	Advanced Separation Processes	3	0	-	3
3.	PD 1103 PD 1104 PD 1105 PD 1106 PD 1107	Prog. Elective - I	1. Advanced Fluid Dynamics 2. Advanced Heat Transfer 3. Bio Energy Engineering 4. Non-Conventional Energy 5. Solid Waste Management	3	0	-	3
4.	PD 1108 PD 1109 PD 1110 PD 1111 PD 1112	Prog. Elective - II	1. Process Plant Simulation 2. Advanced Fluidization Engineering 3. Pinch Technology 4.Multi Component Mass Transfer 5. Process Intensification	3	0	-	3
5.	PD 1113 PD 1114 PD 1115 PD 1116 PD 1117	Prog. Elective - III	1. Transport in Porous Media 2. Phase transition in Process Equipment 3. Polymer Technology 4. Advance Transport Phenomenon 5. Process Automation				
6.	PD 1201	Lab - I	Process Modeling and Simulation laboratory	-	-	4	2
7.	PD 1202	Lab - II	Advanced separation processes	-	-	4	2
8.	RMC 1101	Common Paper	Research Methodology &IPR	2	-	-	2
9.	**A10001** **A10002** **A10003** **A10004**	Audit I	1. English for Research Paper Writing 2. Professional Ethics 3. Stress Management by Yoga 4. Constitution of India	2	-	-	0
	Total Credits						**21**

Course Structure M. Tech. (Plant Design)
Academic Session 2021-22onwards
SEMESTER II

S. No.	Course Code	Course	Subject	L	T	P	Cr.
1.	PD 2101	Core - III	Advanced Process Control	3	0	-	3
2.	PD 2102	Core - IV	Advanced Process Equipment Design	3	0	-	3
3.	PD 2103 PD 2104 PD 2105 PD 2106 PD 2107	Prog. Elective - IV	1. Advanced Thermodynamics 2. Membrane Science and Technology 3. Interfacial Science and Engineering 4. Nano Science and Technology 5. Process Plant Design and Flow sheeting	3	0	-	3
4.	PD 2108 PD 2109 PD 2110 PD 2111 PD 2112	Prog. Elective - V	1. Industrial Pollution Control 2. Advanced Chemical Reaction Engineering 3. Modern concepts in Catalysis and Surface Phenomenon 4. Process Design and Synthesis 5. Industrial Safety	3	0	-	3
5.	PD 2113 PD 2114 PD 2115 PD 2116 PD 2117	Open. Elective - I	1. Business Analytics 2. Operations Research 3. Cost Management of Engineering Projects 4. Composite Materials 5. Computational Fluid Dynamics (NPTEL)				
6.	PD 2201	Lab - III	Advanced Chemical Reaction Engineering laboratory	-	-	4	2
7.	PD 2202	Lab - IV	Advanced Process Dynamics Lab	-	-	4	2
8.	PD 2203	Mini Project	Mini Project	-	-	4	2
9.	**A20001** **A20002** **A20003** **A20004**	Audit II	1. Disaster Management 2. Value Education 3. Soft Skills 4. Personality Development through Life Enlightenment Skills.	2	-	-	0
	Total Credits						**21**

Course Structure M. Tech. (Plant Design)
Academic Session 2021-22 onwards
SEMESTER III

S. No.	Subject Code	Course	Subject	L	T	P	Cr.
1.	PD 3201	Dissertation	Dissertation Phase – I	-	-	20	10
Total Credits							**10**

SEMESTER IV

S. No.	Subject Code	Course	Subject	L	T	P	Cr.
1.	PD 4201	Dissertation	Dissertation Phase – II	-	-	32	16
Total Credits							**10**

SEMESTER I (Syllabus)

Core I(PD 1101): Chemical Engineering Analysis: Application of Mathematical & Statistical Methods

Teaching Scheme:

Lectures: 3 Periods/week — ***Sessional Marks: 40***

University Examination: 3 hours. — ***University Examination Marks: 60***

Objectives:

1. To give students an insight in various Chemical Engineering Processes using advanced Numerical and Statistical Methods.
2. To provide adequate background of Mathematics to deal with Chemical Engineering Problems
3. To understand research papers on relevant topics involving advanced Mathematics.
4. To study Probability concepts and distributions.

Outcomes:

At the end of the course, the student will be able:
1. To solve system of linear algebraic equations
2. To do numerical integrations of functions.
3. To evaluate the eigenvalues of the given function.

Detailed Syllabus

Unit I — **Lectures 8**

Vector and tensor spaces; metric, norm and inner products; orthonormalization; matrices, operators and transformations; eigen values and eigen vectors.

Unit II — **Lectures 8**

Fredholm alternative, Rayleigh quotient and its application to chemical engineering systems; self-adjoint and non-self-adjoint systems; partial differential equations and their applications in chemical engineering;

Unit III — **Lectures 8**

Strum-Liouville Theory; Separation of variables and Fourier Transformations; application of Greens Function for solution of ODE and PLDEs in chemical engineering; numerical techniques for solution of ODE and PDEs; linear stability and limit cycles; bifurcation theory; secondary bifurcation and chaos.

Unit IV — **Lectures 10**

Probability concepts and distributions, random variables, error analysis, point estimation and confidence intervals, hypothesis testing.

Unit V — **Lectures 8**

Development of empirical chemical engineering models using regression techniques, design of experiments, process monitoring based on statistical quality control techniques. Case studies.

Text Books/References:

1. Mathematical Methods in Chemical Engineering: S. Pushpavanam; Prentice Hall of India ISBN: 81-203-1262-7., 1998
2. Introduction to Numerical Methods in Chemical Engineering: Pradeep Ahuja; PHI Learning ISBN: 9788120340183, 2nd Edition, 2010

Core II(PD 1102):Advanced Separation Processes

Teaching Scheme:

Lectures: 3 Periods/week — ***Sessional Marks: 40***

University Examination: 3 hours. — ***University Examination Marks: 60***

Objectives:

1. To familiarize students with various advanced aspects of separation processes and the selection of separation processes.
2. To enable students to understand the principles and processes of distillation, multicomponent separation and to design an absorber or a distillation unit to achieve a specified separation.
3. To introduce them to new trends used in the separation technologies.

Outcomes:

At the end of the course, the student will be able to**:**

1. Calculate the no of stages
2. Design an absorption column

Detailed Syllabus:

Unit I — **Lectures 10**

Introduction: Conventional separation processes - Absorption, Adsorption, Conventional separation processes - Distillation, Drying, Conventional separation processes - Extraction, Diffusion, Conventional separation processes - Leaching, Crystallization, Advances in separation techniques based on size, Advances in separation techniques based on surface properties, Advances in separation techniques based on ionic properties, Cross flow filtration, Electro filtration, Dual functional filter, Surface based solid-liquid separations involving a second liquid, Sirofloc filter

Unit II — **Lectures 10**

Mechanism of Transfer:

Expression for diffusion coefficient in gases and liquids, Von Karman and Marternell; analogy for transfer, Knudsen diffusion, thermal diffusion, recent theories of inter phase transfe.

Multicomponent distillation:

Determination of key components at minimum reflux ratio by the method of shiras et.al: Minimum reflux ratio by Underwood's method; Fenske equation for total reflux and computation of product distribution; Flash vaporization of feed to the distillation column; Rigorous methods of Lewis-Matheson, Thiele-Geddes, bubble point, sum rates method.

Unit III — **Lectures 06**

Azeotropic distillation:

Stage wise calculations for multicomponent with multiple feed streams, graphical method for location of feed plates for multiple feeds.

Unit IV — **Lectures 06**

Liquid-Liquid Extraction:

Stage wise calculations for multicomponent with multiple feed streams using reflux and mixed solvents.

Unit V — **Lectures 10**

Multicomponent Gas Absorption:

Horton-Franklin method, Edmister method. Mass transfer in gas absorption with and without chemical reaction, model solution by Dankwerts; Brian; Perry and Pigford.

Text Books/Reference Books:

1. Diffusional Mass Transfer – A.H.P. Skelland, Wiley Inter-Science, 1974
2. Absorption & Extraction – T.K. Sherwood & R.L. Pigford – McGraw Hill, 1952
3. Mass Transfer – T.K. Sherwood, R.L. Pigford& C.R. Wilke – McGraw Hill, 1975
4. Mass Transfer with Chemical Reaction – G. Astarita – Elsevier, 1967
5. Gas Liquid Reactions: Danckwerts, 1970
6. Gas Liquid Heterogeneous Reactions: Doraiswamy and Sharma, 1984

Program Elective I (a)(PD 1103)
ADVANCED FLUID DYNAMICS

Teaching Scheme:

Lectures: 3 Periods/week — ***Sessional Marks: 40***

University Examination: 3 hours. — ***University Examination Marks: 60***

Unit I — **Lectures 9**

Flow Dynamics:

Continuity equation in linear and curvilinear coordinates, Momentum, equations, idea flow, Euler's equations of motion, Velocity potential, rotational and irrotational flow; Naiver-Stokes equation, Poiseuille flow, creep flow and Couette flow.

Unit II — **Lectures 7**

Boundary layer theory: integral momentum analysis. Turbulent boundary layer: turbulence and mixing. Universal velocity profile. Stability analysis of laminar flow, Orr-Somerfield Solution, modeling of turbulent flow.

Unit III — **Lectures 6**

Laminar and turbulent flow of non-Newtonian fluid. Rheological characteristics, consistency measurement, viscometric flow, pipeline design equation.

Fluidization:

The phenomena of fluidization and its industrial application.

Unit IV — **Lectures 9**

Characteristics of particles. Principle of fluidization and mapping of various regimes. Two phase theory of fluidization. Liquid-solid and gas solid fluidized beds, entertainment and Elutriation. Fast circulating and semi-fluidized bed. Mixing and segregation.

Unit V — **Lectures 5**

Introduction to three phase fluidizations. Heat and Mass transfer in fluidized bed. Design of fluidized bed reactors.

Text Books/Reference Books:

1. Fluid Dynamics & Heat Transfer – J.G. Kundsen& D.L. Katz, McGraw Hill Book Co.Inc.
2. Fluidization Engineering – D. Kunil& O. Levenspiel, Willey International Education.

Program Elective I (b) (PD 1104)
ADVANCED HEAT TRANSFER

Teaching Scheme:

Lectures: 3 Periods/week	***Sessional Marks: 40***
University Examination: 3 hours.	***University Examination Marks: 60***

Objective: The present course aims to help the student to understand various heat transfer mechanism in unsteady state and advances in convection, turbulent flows and radiation.

Prerequisites: Knowledge of basics of conduction, convection, radiation and heat transfer equipments design.

COURSE OUTLINE

Unit I **Lectures 6**

Heat condition: Introduction, extended surfaces, lumped system analysis, transient heat conduction in large plane walls, long cylinders and spheres, transient heat conduction in semi-infinite solids, numerical solution of multi-dimensional conduction problems, transient heat conduction charts.

Unit II **Lectures 6**

Convection: convective heat transfer-theories and practices, laminar boundary layer on a flat plate, energy equation for thermal boundary layer over a fiat plate, momentum and heat exchange in turbulent fluid flow, flow across spheres, cylinders and tube banks.

Unit III **Lectures 6**

Heat transfer with phase change: Boiling- regimes of pool boiling and heat transfer during boiling, Condensation- drop wise and film wise condensation, effect of turbulence and high velocity on film wise condensation.

Unit IV **Lectures 12**

Heat exchanger design: Basic design procedure and theory - overall heat transfer coefficients, fouling factors; type of heat exchangers- shell and tube, plate, direct contact, finned tubes, air cooled and Compact heat exchangers, Efficiency of heat exchangers and number of transfer units, (N.T.U.)

Unit V **Lectures 6**

Heat transfer in packed bed, fluidized bed and nuclear reactors - basic fundamental and factors affecting the rate of heat transfer, heat transfer in liquid metals

Text Books/Reference Books:

1.Sinnott, R. and Towler, G., “Chemical Engineering Design”, Vol. 6, Coulson & Richardson’s Chemical Engineering Series, 5th Eddition, Elsevier, 2009

2. Holman, J. P., Heat Transfer, Tata McGraw Publication, 9th Edition, 2002.

3. Tong, L. S., and Tang, Y. S., “Boiling Heat Transfer and Two-Phase Flow”, 2nd Edition, Taylor& Francis 1997. 4. S. G. Kandlikar, "Handbook of Phase Change: Boiling and Condensation" Taylor & Francis, 1999.

Program Elective I (c) (PD 1105)
BIO-ENERGY ENGINEERING

Teaching Scheme:

Lectures: 3 Periods/week — ***Sessional Marks: 40***

University Examination: 3 hours. — ***University Examination Marks: 60***

Unit I **Lectures 10**

Biomass sources, Characteristics & Preparation: Biomass sources and Classification. Chemical composition and properties of different biomass materials and bio-fuels. Sugar cane molasses and other sources for fermentation ethanol – Sources and processing of oils and fats for liquid fuels – Energy plantations – Preparation of woody biomass: Size reduction, Briquetting of loose biomass, drying, storage and handling of biomass.

Unit II **Lectures 10**

Biogas Technology: Feedstock for biogas production, Aqueous wastes containing biodegradable organic matter, animal residues – Microbial and biochemical aspects – Operating parameters for biogas production, Kinetics and mechanism – Dry and wet fermentation. Digesters for rural application – High rate digester for industrial waste water treatment.

Unit III **Lectures 10**

Bio-Ethanol and Bio-diesel Technology: Production of fuel ethanol by fermentation of sugars. Gasohol as a substitute for leaded petrol. – Trans-Esterification of oils to produce Bio-Diesel.

Unit IV **Lectures 10**

Pyrolysis and Gasification of Biomass: Thermo-chemical conversion of lingo-cellulose biomass – Biomass processing for liquid fuel production – Pyrolysis of biomass, Pyrolysis regime, effect of particle size, temperature, and products obtained. Thermo-chemical gasification principles: Effect of pressure, temperature and of introducing steam and oxygen. Design and operation of fixed and fluidized bed gasifiers.

Unit V **Lectures 10**

Combustion of Biomass and Cogeneration Systems: Combustion of woody biomass: Theory, calculations and design of equipments. Cogeneration in biomass processing industries. Case studies: Combustion of rice husk, Use of bagasse for cogeneration.

Text Books/Reference Books:

1. A. Chakravarthy: Biotechnology & Alternative Technologies for Utilization of Biomass or Agricultural Wastes, Oxford & IBH Publishing Co., New Delhi, 1989.
2. K.M. Mital: Biogas Systems: Principles & Applications, New Age International Publishers (P) Ltd., 1996.
3. P. Venkata Ramana & S.N. Srinivas: Biomass Energy Systems, Tata Energy Research Institute, New Delhi 1996.
4. D.L. Klass& G.M. Emert: Fuels from Biomass & Wastes, Ann Arbor Science Pub. Inc, Michigan, 1985.
5. Khandelwal, K.C. & Mahdi: Bio-gas Technology, Tata McGraw Hill Pub. Co.
6. O.P. Chawla: Advances in Bio-Gas Technology, ICAR, New Delhi 1970.

Program Elective I (d) (PD 1106)
Non-Conventional Energy

Teaching Scheme:
Lectures: 3 Periods/week ***Sessional Marks: 40***
University Examination: 3 hours. ***University Examination Marks: 60***

Course Outcomes: At the end of the course, the student will be able to:

CO1: Describe the challenges and problems associated with the use of energy sources.
CO2: List renewable energy resources and technologies.
CO3: Design conversion technologies for solar, wind, biomass and hydrogen energies.
CO4: Evaluate the performance of energy conversion technologies

Prerequisites: None

Detailed syllabus

Unit I **Lectures 10**
Sources of energy: Energy sources and their availability, renewable energy sources.

Energy from Biomass: Introduction, Biomass as a source of energy, Biomass conversion technologies, Biogas generation, classification of biogas plants, Biomass gasification.

Unit II **Lectures 6**
Solar Energy: Sun and solar energy, solar radiation and its measurement, solar energy collectors, solar energy storage, Photovoltaic systems, Application of solar energy

Unit III **Lectures 6**
Wind Energy: Wind as an Energy source, Basic principles of wind energy conversion, Types of Wind machines, Components of wind energy conversion system, Performance of wind machines, application of wind energy.

Unit IV **Lectures 6**
Geothermal Energy: Introduction, Origin and distribution of geothermal energy, types of geothermal resources, Hybrid geothermal power plant, Application of geothermal energy Hydrogen energy: Introduction, Hydrogen production, Hydrogen storage,

Unit V **Lectures 6**
Hydrogen transportation Energy from the Oceans: Introduction, Ocean Thermal Electric Conversion (OTEC), Energy from Tides, Ocean Waves Chemical Energy Sources: Introduction, Fuel cells, Batteries.

Text Books/Reference Books:

1. Rai, G.D, Non-Conventional Energy Sources, Khanna Publishers, New Delhi, 2010.
2. Rajesh Kumar Prasad, T.P. Ojha, Non-Conventional Energy Sources, Jain Brothers, 2012.
3. Sukhatme S.P and J. Nayak, Solar energy – Thermal Collection and storage, 3rd Edition, Tata McGraw Hill Education Pvt Ltd., 2008.
4. MM. EI – Wakil, Power Plant Technology, Tata McGraw Hill, NewYork, 1999

Program Elective I (e) (PD 1107)
SOLID WASTE MANAGEMENT

Lectures: 3 Periods/week ***Sessional Marks: 40***
University Examination: 3 hours. ***University Examination Marks: 60***

Course objective:
This course will give the idea about the solid waste management (SWM), equipment and processing technique for SWM, properties of municipal solid waste and disposal of SWM.

Course outcome:
At the end of the course, the student will be able to
CO1: Idea about the solid waste management.
CO2: Outline sources, types and composition of solid waste with methods of handling, sampling and storage of solid waste
CO3: Select the appropriate method for solid waste collection, transportation, redistribution and disposal
CO4: Describe methods of disposal of hazardous solid waste.

Detailed Syllabus

UnitI **Lecture 8**
Introduction
Philosophy and organization, Status of waste management, Computation an integrated waste management strategy. Evolution of solid waste management, Legislation and Government agencies

UnitII **Lecture 8**
Management
Planning solid waste management progress, Generation of solid waste, Onsite handling, Storage and processing, Transfer and transport, Processing techniques and equipment, Hazardous waste and their management, Process management issues, Planning, Recovery of resources conservation, Chemical and Biological methods.

UnitIII **Lecture 8**
Properties of Municipal Solid Waste
State the Physical, Chemical and Biological properties, Describe associated considerations of Municipal Solid Waste (MSW)

UnitIV **Lecture 8**
Disposal of solid waste
Land filling, Ocean disposing, Source reduction, Recycling, Incineration, Composting.

UnitV **Lecture 8**
Case studies on major industrial solid waste generation units
Coal fired, power plant, Textile industry, Brewery, Distillery, Oil refinery, radioactive generation units. Case studies on spills, Sludge lagooning and incineration.

Text Books/Reference Books:
1. Solid Waste, Martell, 1975, John Wiley, NY.
2. Solid Waste, George Techobanuglour, H. Theisen and R. Eliassen.
3. Handbook of Solid Waste by Frank Krieth, 1996, McGraw Hill Inc. NY.

Program Elective II (a) (PD 1108)
Process Plant Simulation

Teaching Scheme:

Lectures: 3 Periods/week — ***Sessional Marks: 40***

University Examination: 3 hours. — ***University Examination Marks: 60***

Course Objectives:

1. To understand the process involving in a chemical plant

2. To simulate steady and unsteady state process parameter for a plant

Course Outcomes: At the end of the course, the student will be able to:

1. Partition and tear different parts of chemical equipment
2. Simulate a change in the real process
3. Model different processes with the help of software.

Detailed Syllabus

Unit I — **Lectures 8**

Introduction and fundamentals of process modeling and simulation, Models in chemical engineering

Unit II — **Lectures 12**

Simulation of steady state lumped systems including simultaneous solution, modular solution, nested inside-out algorithms, partitioning and tearing with reference to chemical process equipments like reactors; distillation, absorption, extraction columns; evaporators; furnaces; heat exchangers; flash vessels etc.

Unit III — **Lectures 06**

Unsteady state lumped systems and dynamic simulation;

Unit IV — **Lectures 06**

Introduction to application of advanced Artificial intelligence-based modeling methods using Artificial Neural Networks

Unit V — **Lectures 8**

Traditional and non-traditional optimization techniques. Case study using professional software packages.

Text Books/Reference Books:

1. Process Plant Simulation, B. V. Babu, Oxford University Press., 2004
2. Process Analysis and Simulation in Chemical Engineering, Iván Dario Gil Chaves, Springer, 2015

Program Elective II (b) (PD 1109)
Advanced Fluidization Engineering

Teaching Scheme:

Lectures: 3 Periods/week — ***Sessional Marks: 40***

University Examination: 3 hours. — ***University Examination Marks: 60***

UNIT I — **Lectures 06**

Introduction: Fluidization, Fluidized beds, Gross behavior of fluidized beds, Minimum fluidizing velocity and pressure drops, Transport disengaging height, Regimes.
The Dense bed: Bubbles in Dense Beds; Single Rising Bubbles, Coalescence and Splitting of Bubbles
Physical Models: Davidson Model, stream of bubbles, bubbling bed models, Emulsion phase, Turn-over rate of solids.

UNIT II — **Lectures 06**

Gas Dispersion and Gas Interchange in Bubbling Beds: Residence time distribution diffusion model of solids movement, interchange coefficient into and out a wake; Diffusion model for gas flow; two region models, evaluation of interchange coefficients.

UNIT III — **Lectures 10**

Particle-to-Gas Mass and Heat Transfer: Mass and heat transfer between fluids and solid from bubbling bed model,
Conversion of Gas in Catalytic Reactions: Catalytic conversion from bubbling bed model; contacting efficiency; application to successive reactions
Heat Transfer between Fluidized Beds and Surfaces: Theories and bed-wall heat transfer; comparison of theories. Entrainment and elutriation, application of' entrainment model

UNIT IV — **Lectures 10**

The RTD and Size Distribution of Solids in Fluidized Beds: Residence time distribution and size distribution of solids in fluidized beds, particles of changing size.
Circulation Systems: Circulation rates of solids, flow of high and low hulk density mixtures.

UNIT V — **Lectures 10**

Design for Physical Operations: Catalytic Reactors; Bench-Scale and Pilot-Plant Reactors, Design Decisions, Deactivating Catalysts. Noncatalytic Gas-Solid Reactors; Kinetic Models for the Conversion of Solids, Conversion of Solids of Unchanging Size, Conversion of Shrinking and Growing Particles, Conversion of Gas and Solids, Miscellaneous Extensions.

Text Books/Reference Books:

1. J. F. Davidson and D. Harrison, Fluidization, Academic Press, 1971.
2. D. Kunii and O. Levenspiel, Fluidization Engineering, John Wiley, 1969.
3. F. A. Zenz and D. F. Othmer, Fluidization and Fluid Particle System, Reinhold Publishing, 1960.

Program Elective II (c) (PD 1110)
PINCH TECHNOLOGY

Teaching Scheme:
Lectures: 3 Periods/week ***Sessional Marks:40***
University Examination: 3 hours. ***University Examination Marks: 60***

Prerequisite: Heat Transfer Operation, Chemical Engineering Thermodynamics, Mass transfer Operation, Basics of Chemical Reaction Engineering and Numerical methods

Objective:

The main objective is to study the methodology for minimizing the energy consumption in any chemical industry. The subject will provide the knowledge of calculating minimum energy consumption by optimizing the heat recovery system in designing stage and process operating conditions.

Content
Introduction to Pinch Technology, Pinch Methodology, Pinch Design and Optimization, Energy Resources analysis for various processes and mass exchange network.

Course Outcome
Student will be able to
- Built the basis knowledge of Pinch Technology and Optimization.
- Review the importance of heat recovery and energy conservation in chemical industries.
- To apply Pinch methodology and design; using different thermodynamic equations.
- Do the heat recovery analysis and its optimization.

Detailed Syllabus

UNIT I **Lectures 10**
Introduction to Pinch Technology
Locating the Pinch, significance of Pinch, Threshold problems, capital cost implication or the pinch Targeting, Heat exchanger networks, energy targeting, area targeting, unit targeting, shell targeting, cost targeting, super targeting, continuous targeting

UNIT II **Lectures 10**
Pinch Methodology
Problem representation, temperature enthalpy diagram. Simple match matrix. Heat content diagram, Temperature interval diagram, Heuristic approach &PDM, weighted flowrate specific heat method (WFCPM), Tree searching

UNIT III **Lectures 08**
Pinch Design
Networks for maximum energy recovery, Pinch design method, Flexibility criteria of the pinch, CP table, the tick or heuristic, case studies

UNIT IV **Lectures 07**
Optimization
Optimization or heat exchanger network optimality for a minimum area network, Sensitivity analysis.

UNIT V **Lectures 06**
Energy and resource analysis or various processes and mass exchange network(11L+4T)

Batch process, flexible process, Distillation process, evaporation process, reaction process, process using mass separatingagent, Heatpipes and Heat pumps, MEN Network, Waste minimization by using mass separating agents.

Text Books/Reference Books:

1. "Heat exchanger network synthesis: Process Optimization by Energy and Resource Analysis", Uday V. Shenoy, Gulf Publishers
2. "Chemical Process Synthesis and Engineering Design", Anil Kumar, Tata McGraw Hill
3. "Process Heat Transfer", D. Q. Kern, McGraw Hill
4. "Chemical Engineering design" Gavin P. Towler, 5th Edition, Butterworth-Heinemann,2009

Program Elective II (d) (PD 1111)
MULTI COMPONENT MASS TRANSFER

Teaching Scheme:
Lectures: 3 Periods/week ***Sessional Marks: 40***
University Examination: 3 hours. ***University Examination Marks: 60***

Objective: To emphasize on the concepts used in distillation absorption and extraction operations for multi-component mass transfer.

Prerequisites: Basic course of mass transfer

Detailed Syllabus

UNIT I **Lectures 4**
Introduction: Overview of binary systems: Gibbs phase rule, flash, bubble point and dew point calculations, diffusive, equilibrium and rate-based methods.

UNIT I I **Lectures 8**
Multicomponent cascade systems: Cascade configurations, liquid-liquid extraction cascades, vapour liquid cascades, membrane cascades, specifications for counter current cascades.

UNIT III **Lectures 8**
Approximate methods for multi-component-multistage separation: Fenske-Underwood-Gilliland method, Fenske equation for minimum equilibrium stages, Underwood equations for minimum reflux, Gilliland correlation for actual reflux ratio and theoretical stages, Kramser Group method for strippers and liquid-liquid extraction.

UNIT I V **Lectures 8**
Equilibrium based methods for multi-component systems: Theoretical model for equilibrium stage, general strategy of mathematical solution, equation –tearing procedure: Bubble point method for distillation, sum rates method for absorption and stripping, Newton Raphson method, MESH equations.

UNIT V **Lectures 10**
Design of multi-component systems: Design of multi-component distillation column using Lewis-Matheson method, azeotropic and extractive distillation, reactive multistage separations, diffusion in non-ideal system and development of generalized Maxwell-Stefan formulation, Study of generalized Fick' s law.

Text Books/Reference Books:

1. Seader J. D.; Henly E. J., Separation Processes and Principles, John Wiley, 2010, 3nd edition.
2. Taylor R.; Krishna R., Multicomponent Mass Transfer, John Wiley, 1993.
3. Bendaitez J. Principles and Modern Applications of Mass Transfer Operations, Wiley, 2nd edition, 2011.
4. Holland, C. D. Fundamentals of Multicomponent Distillation, McGraw Hill, 1981.
5. Wankat P. C., Separation Process Engineering, Prentice Hall, 2011, 3nd edition.

Program Elective II (e) (PD 1112)
PROCESS INTENSIFICATION

Teaching Scheme:

Lectures: 3 Periods/week | ***Sessional Marks: 40***

University Examination: 3 hours. | ***University Examination Marks: 60***

Objective: This course is aimed to provide the insights of compact, safe, energy-efficient and environmentfriendly novel equipments and processes.

Prerequisites: Knowledge of basic chemical engineering courses particularly mass transfer, heat transfer and reaction engineering.

Detailed Syllabus

UNIT I **Lectures 4**

Need of process intensification, process intensifying equipments and methods, examples of their application on the commercial scale.

UNIT II **Lectures 9**

Use of high gravity fields, higher reactor, spinning disc reactors, micro-channel heat exchangers.

UNIT III **Lectures 9**

Monolithic catalyst and reactors, reverse flow reactor, micro-reactors.

UNIT I V **Lectures 9**

Concept and principle, reactive- distillation, extraction, precipitation adsorption, absorption, fermentationpervaporation, adsorptive distillation, membrane reactors and bioreactors.

UNIT V **Lectures 4**

Industrial practice (methodology, application) PI by improvement in existing plant and process synthesis, pi by plants safety.

Text Books/Reference Books:

1. Stankiewicz, A.; Moulijn, J.A. “Re-engineering the chemical processing plant: process intensification” Marcel Dekker, Inc., New York, 2004.
2. Mizrahi, J. “Developing an industrial chemical process: an integrated approach” CRC Press, 2002.
3. Keil, F.J. “Modeling of Process Intensification” Wiley-VCH Verlag Germany, 2007
4. Reay, D.; Ramshaw, C.; Harvey, A. “Process Intensification” Elsvier, 2013
5. Boodhoo, K.; Harvey, A. “Process Intensification for Green Chemistry”, Wiley, 2013

Program Elective III (a) (PD 1113)
Transport in porous Media

Teaching Scheme:
Lectures: 3 Periods/week ***Sessional Marks: 40***
University Examination: 3 hours. ***University Examination Marks: 60***

Course Objectives:
1. Introduce the physics and governing mechanisms controlling flow and transportprocessesinporous media.
2. Learning Liquid and solute transport in porous media.

Course Outcomes: At the end of this course, students will be able to:
1. Understand the mechanisms involved in transport processes in porous media.
2. Apply the equations that govern the fate and transport of gas, water and solutesin porous media.

Unit-I: **Lectures 6**
Fundamentals: Mass, momentum and energy transport, Darcy and Non-Darcy equations, equilibrium and non-equilibrium conditions, species transport, radioactive decay.

Unit-II: **Lectures 8**
Effective medium approximation: equivalent thermal conductivity, viscosity, dispersion.

Unit-III: **Lectures 10**
Exact solutions: Flow over a flat plate, flow past a cylinder, boundary-layers, reservoir problems.

Unit-IV: **Lectures 8**
Special topics: Field scale and stochastic modeling, Turbulent flow, compressible flow, multiphase flow, numerical techniques, hierarchical porous media, nanoscale porous media, multi-scale modeling.

Unit-V: **Lectures 8**
Engineering applications: Groundwater, waste disposal, oil and gas recovery, regenerators, energy storage systems. Experimental techniques: Flow visualization, quantitative methods, inverse parameter estimation.

Text Books/Reference Books:

1. Principles of Heat Transfer in Porous Media, by M. Kaviany, Springer New York (1995).
2. Transport Phenomena in Porous Media, Volumes I-III, edited by D. R. Ingham and I. Pop,Elsevier, New York (1998-2005).
3. Dynamics of Fluids in Porous Media, J. Bear, Dover (1988).
4. Introduction to Modeling of Transport Phenomena in Porous Media, J. Bear and Y.Bachmat,Kluwer Academic Publishers, London (1990).
5. Enhanced Oil Recovery, L.W. Lake, Gulf Publishing Co. Texas (1989).
6. The Mathematics of Reservoir Simulation, R.E. Ewing, SIAM Philadelphia (1983).
7. Stochastic Methods for Flow in Porous Media: Coping with Uncertainties, Zhang, D.,Academic Press, California (2002).
8. The Method of Volume Averaging, S. Whitaker, Springer, New York (1999).

Program Elective III (b) (PD 1114)
Phase transitions in Process Equipment

Teaching Scheme:
Lectures: 3 Periods/week ***Sessional Marks: 40***
University Examination: 3 hours. ***University Examination Marks: 60***

Objectives:
1. Basic laws in thermodynamics.
2. Basic statistical concepts and methods: heat, work, energy, temperature and thekinetic theoryof matter; entropy, ensemble, partition function, etc
3. Learning phase transition catalysis
4. Have a good grasp of the basic thermodynamic interactions and process: adiabatic, isothermal, etc

Outcomes: At the end of this course, students are able to:
1. The student is expected to obtain considerable insight into various types of phasetransitions,and how these can be described theoretically in different ways
2. Predict relationships between physical quantities using the laws and methods ofthermodynamics.
3. Find probabilities and thermal quantities (free energy, entropy, etc) given the energyeigenvalues of a system.

Unit-I: **Lectures 6**
Thermodynamic aspects of phase transitions: Concept of phase, First-order phase transition, conditions for phase coexistence lines, free energy barrier of nucleation, and crystal-melt interfacialfree energy, Ehren-fest classification of phase transitions, Van der Waals equation of state, Criticalpoint

Unit-II: **Lectures 6**
Single phase and multiphase catalytic reactions, Acid--base catalysis, Transition metalcatalysis, Phase transfer catalysis, Micellar catalysis, Micro-emulsion catalysis, Electron transfercatalysis, Heteropoly acid catalysis, Homogeneous polymer catalysis, Heterogenization ofhomogeneous catalysts.

Unit-III: **Lectures 8**
Applications to Multi-phase Systems Stability conditions for a homogeneous system,equilibrium between phases, phase transformations, general relations for a system with severalcomponents, general conditions for chemical equilibrium, chemical equilibrium between idealgases,and the equilibrium constants in terms of partition functions.

Unit-IV: **Lectures 8**
Phase diagrams and transformations Phase rule- single and binary phase diagrams, leverrule, micro structural changes during cooling, Al_2O_3, Cr_2O_3, Pb-Sn, Ag-Pt and Fe-Fe_3C Systemsphase diagrams, phase transformations, corrosion- theories of corrosion, control and prevention ofcorrosion

Unit-V: **Lectures 6**
Energy balance - heat capacity and calculation of enthalpy changes, Enthalpy changes forphase transitions, evaporation, clausius - clapeyron equation,

Text Books/Reference Books:

1. Hegedus, L.S., Transition Metals in the Synthesis of Complex Organic Molecules,UniversityScience Book (2010) 3rd ed.
2. Raghavan V., Material Science and Engineering Prentice Hall of India, 1996
3. David.M.Himmelblau, "Basic principles and calculations in chemical engineering",PrenticeHall of India Ltd., 6th Edition, 1998.
4. A.Hougen, K.M. Watson and K.A.Ragatz, "Chemical Process Principles", Vol 1, John Wiley,1960.

Program Elective III (c) (PD 1115)
Polymer Technology

Teaching Scheme:

Lectures: 3 Periods/week ***Sessional Marks: 40***

University Examination: 3 hours. ***University Examination Marks: 60***

Objectives:

1. To get the basic concepts of polymers such as types, structure, forces, thermal transition and bonding in polymers.
2. To develop the deep knowledge on Polymer preparation and various methods of processing.
3. To give knowledge on properties and characterization techniques of polymers.
4. To learn about Polymer additives, blends and composite.
5. To address the developments in polymer processes, management and applications of polymers.

Outcomes:

At the end of the course, the student will be able to**:**

1. Understanding the fundamentals of polymers.
2. Analyze the formation of polymers, polymeric composites and their blends.
3. Investigate the polymeric materials through characterization techniques

Unit I **Lectures 6**

Introduction to polymers: Basic concepts and definitions, classification of polymers, polymer structure, molecular forces and chemical bonding in polymer, molecular weight and its distribution, chemical structure and thermal transition.

Unit II **Lectures 8**

Polymer preparation and processing methods: Step-reaction (condensation) polymerization, radical chain (addition) polymerization, ionic and coordination chain (addition) polymerization, copolymerization, polymerization conditions and polymer reactions. Various polymeric processing methods.

Unit III **Lectures 10**

Polymer characterization: Characterization - molecular weight and molecular size determination, thermoanalytical methods of characterization including TGA, DTA, and DSC; spectroscopy (IR, NMR, UV-visible) of polymers. Properties – solution properties, mechanical properties and polymer viscoelasticity.

Unit IV **Lectures 8**

Polymer additives, blends and composites: Additives – plasticizers, fillers and reinforcements, other important additives. Polymer blends and interpenetrating networks - polymer blends, toughened plastics and phase-separated blends, interpenetrating network. Introduction to polymer composites – Mechanical properties, composite fabrication.

Unit V **Lectures 6**

Specific topics in polymer technology: Biodegradable polymers, Scale up of polymerization processes, recent developments in polymer processes, applications of the polymers in various fields, management of polymeric products in the environment.

Text Books/Reference Books:

1. J. O. Fried, “Polymer science and technology”, 3rd Edition, Prentice Hall Publisher, 2014
2. R. R. Ebewele, “Polymer science and technology”, CRC Press, Boca Raton, New York 2000.
3. F. W. Billmeyer, “Textbook of polymer science”, 3rd Edition, A Wiley-lnterscience Publication 1984.
4. T. Meyer and J. Keurentjes, “Handbook of polymer reaction engineering”, A Wiley-VCH Publication 2008.
5. S. Palsule, “Polymer composites”, New Age International 2008.
6. P. M.Ajayan, L. S Schadler., P. V Braun., “Nanocompositescience&technology”, Wiley-VCH 2003

Program Elective III (d) (PD 1116)
ADVANCED TRANSPORT PHENOMENA

Teaching Scheme:

Lectures: 3 Periods/week ***Sessional Marks: 40***

University Examination: 3 hours. ***University Examination Marks: 60***

Objective:

To develop an understanding of momentum, heat and mass transport in Chemical Engineering as well as in process industries. Prerequisites: Basic knowledge of undergraduate chemical engineering courses particularly heat transfer, mass transfer and fluid mechanics.

COURSE OUTLINE

Unit I **Lectures 7**

Fundamentals of transport processes, basics of vector and tensor algebra, phenomenological equations and transport properties, analogies amongst momentum, heat, and mass transport; non-Newtonian fluids and rheological behavior.

Unit II **Lectures 10**

Basic transport equations for isothermal, non-isothermal and multicomponent systems; velocity, temperature and concentration distributions with more than one independent variables; velocity, temperature and concentration distributions in laminar and turbulent flow.

Unit III **Lectures 10**

Macroscopic balances for isothermal, non-isothermal and multicomponent system and their applications in momentum, heat and mass transport problems; simultaneous momentum, heat and mass transfer with chemical reaction.

Unit IV **Lectures 5**

Analytical methods for solution of transport equations

Unit V **Lectures 5**

Computational methods involve in multiphase flow, chemically reacting flows, turbulent mixing etc.

Text Books/Reference Books:

1. Bird, R.B., Stewart, W.E. and Lightfoot, E.N., “Transport Phenomena”, 2nd Edition, John Wiley & Sons, 2002.
2. Deen, W.M.,“Analysis of Transport Phenomena”, Oxford University Press, 1st Edition, 2008.
3. Slattery, J.., “Advanced transport phenomena”, Cambridge University Press, 1999.
4. Leal, L. “Advanced Transport Phenomena: Fluid Mechanics and Convective Transport Processes”, Cambridge University Press, 2007.
5. Geankoplis C.J. “Transport Processes and Separation Process Principles” Prentice Hall, 2003.

Program Elective III (e) (PD 1117)
PROCESS AUTOMATION

Teaching Scheme:

Lectures: 3 Periods/week ***Sessional Marks: 40***
University Examination: 3 hours. ***University Examination Marks: 60***

Course Outcomes: At the end of the course students are able to

CO1: Demonstrate the concepts of instrumentation for the measurement, control and classification of systems by utilizing the analog / digital control devices.
CO2: Develop the skills required for automation, control and monitoring of industrial processes in high level with automation and control systems.
CO3: Employ high-level PLC control systems in the computer integration of manufacturing processes.

Unit I **Lectures 06**
INTRODUCTION
Principles of measurement and classification of process control instruments, temperature, pressure fluid flow, liquid level, velocity, fluid density, viscosity etc.

Unit II **Lectures 06**
INSTRUMENTS
Instrument scaling, sensors, transmitters and control valves, instrumentation symbols and labels.

Unit III **Lectures 10**
PROCESS AUTOMATION
Structure &components of Industrial Automation systems. Architectural levels of Industrial controls, Single loop and Multi loop controllers and their tuning.

Unit IV **Lectures 10**
PROGRAMMABLE LOGIC CONTROLLER
Introduction, architecture, definition of PLC, PLC vs PC, PLC vs DCS

Unit V **Lectures 10**
DISTRIBUTED CONTROL SYSTEM

Introduction, functions, advantages, and limitations DCS as automation tool for resource planning and support enterprise

Text Books/Reference Books:

1. Nakara B.C., Choudary K.K., Instrumentation and Analysis, Second Edition, Tata McGraw Hill, New Delhi, Seventh Reprint,2006.

2. Stephanopoulos G., Chemical Process Control, Tata McGraw Hill, New Delhi, 1993.

Lab- I (PD 1201)
Process Modelling and Simulation Laboratory

Lectures: 3 Periods/week

Sessional Marks:50
External Examination Marks: 50

List of Experiments

1. Modelling and Simulation of Double pipe Heat Exchanger
2. Modelling and Simulation of Shell and Tube Hear Exchanger
3. Modelling and Simulation of Condenser
4. Modelling and Simulation of Bubble Cap Distillation Column
5. Modelling and Simulation of Absorption Tower
6. Modelling and Simulation of Pipe networking

Lab- II (PD 1202)
Advanced Separation Processes Laboratory

Lectures: 3 Periods/week

Sessional Marks:50
External Examination Marks: 50

List of Experiments

1. Determination of diffusivity of acetone
2. Diffusivity of Solids
3. Determination of percentage, molal, relative and absolute humidity of Environment
4. Mass transfer with and without Chemical Reaction
5. Separation of Components in Binary Distillation Column
6. Separation of components usingAbsorptioncolumn
7. Separation of components using Liquid-Liquid Extraction
8. Estimation of solvents using gas chromatography
9. Separation of components in UV Spectroscopy

Compulsory Paper : Research Methodology and IPR (RMC 1101)

Syllabus:

Module 1:
Meaning of research problem, Sources of research problem, Criteria Characteristics of agood research problem, Errors in selecting a research problem, Scope and objectives of research problem.
Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations

Module 2:
Effective literature studies approaches, analysis Plagiarism, Research ethics, Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

Module 3:
Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

Module 4:
Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.

Module 5:
New Developments in IPR: Administration of Patent System. New developments in IPR;IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

Reference Books:

1. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science &engineering students'"
2. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"
3. Ranjit Kumar, 2 nd Edition, "Research Methodology: A Step by Step Guide for beginners"
4. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd ,2007.
5. Mayall , "Industrial Design", McGraw Hill, 1992.

SEMESTER II (Syllabus)

Core III ((PD 2101): Advanced Process Control

Teaching Scheme:
Lectures: 3 Periods/week ***Sessional Marks: 40***
University Examination: 3 hours. ***University Examination Marks: 60***

Objectives:
1. To familiarize with different manipulated variable and disturbance associated with process.
2. To understand effect of stability for obtaining different control objectives.
3. To analyze different complex process and advance control method.

Outcomes:
At the end of the course, the student will be able to:
1. Categorize processes according to their response and determine their stability.
2. Formulate control strategy with the help of block diagram for complex process.
3. Implement advance control technique according to control strategy.
4. Design digital controller for real time applications.

Detailed Syllabus

Unit I **Lectures 10**
Review of first and higher order systems, Closed and open loop response, Response toforcing functions, Final control element, Stability analysis, Frequency response, Design of control system, controller tuning.

Unit II **Lectures 05**
Advanced control techniques, cascade, ratio, feed forward, adaptive control.

Unit III **Lectures 07**
Selective controls, computing relays, simple alarms, Kalman filter, Smith predictor, Internal model control, Theoretical analysis of complex processes.

Unit IV **Lectures 12**
Multivariable control analysis of multivariable systems, State space representation, Interaction, Decoupler, Optimal control, Linear quadratic regulator. Review of matrix algebra, Bristol arrays, Niederlinski index- Tuning of multivariable controllers

Unit V **Lectures 8**
Design of distillation column-Number of plates, stages arrangement of double caps, diameter and height of the tower and thickness of the shell. Design of absorption column-number of transfer units, diameter height of the tower and the thickness of the shells.

Text Books/Reference Books:

1. Coughnaowr, D.D.”Process systems Analysis and Control, Mc.Graw –Hill,Inc.
2. Ogata, K. “Modern Control Engineering” Prentice –Hall.

Core IV (PD 2102): Process Equipment Design

Teaching Scheme:
Lectures: 3 Periods/week — ***Sessional Marks: 40***
University Examination: 3 hours. — ***University Examination Marks: 60***

Objectives:
1. To understand the systematic approaches for the development of conceptual chemical process designs
2. To learn the advances in problem formulation and software capabilities which offer the
3. Promise of a new generation of practical process synthesis techniques based directly on Structural optimization.
4. Learning chemical process synthesis, analysis, and optimization principles
5. Product design and development procedure and Process life cycle assessment.

Outcomes: At the end of the course, the student will be able to:
1. Analyze alternative processes and equipment
2. Synthesize a chemical process flow sheet that would approximate the real process
3. Design best process flow sheet for a given product
4. Perform economic analysis related to process design and evaluate project profitability

Detailed Syllabus

Unit I — **Lectures 06**
Introduction to fundamental concepts and principles of process synthesis and design and use of flow sheet simulators to assist process design. Process Flow sheet Models: An Introduction to design,Chemical process synthesis, analysis and optimization.

Unit II — **Lectures 06**
Introduction to commercial process design software., Chemical Process (reactor, heat exchanger, distillation etc) analysis using commercial software

Unit III — **Lectures 12**
Design of non-pressure storage vessel, tall vertical vessels, unfired pressure vessels with internal pressure: Storage vessels and process vessels. Design of unfired pressure vessels with external pressures, end closures, flat plates, domed ends, torispherical, ellipsoidal, hemispherical and conical ends. Design of nozzles, openings and reinforcements and pipe-line design.

Unit IV — **Lectures 8**
Design of double pipe heat exchanger and shell and tube type heat exchanger, Design of evaporators (double and triple effect).

Unit V — **Lectures 10**
Design of distillation column-Number of plates, stages arrangement of double caps, diameter and height of the tower and thickness of the shell. Design of absorption column-number of transfer units, diameter height of the tower and the thickness of the shells.

Text Books/Reference Books:
1. Douglas, J. “Conceptual Design of ChemicalProcesses”,New York, NY: McGraw-Hill
2. Chemical Engineering Design, R. Sinnott, Elsevier Coulson & Richardson’s Vol 6., 4th Edition, 2005

Program Elective IV (a) (PD 2103)

ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS

Teaching Scheme:

Lectures: 3 Periods/week ***Sessional Marks: 40***
University Examination: 3 hours. ***University Examination Marks: 60***

Objective: This course aims to provide insight on phase equilibrium thermodynamics for multi-component systems. A part of the course is devoted to statistical mechanics and its relation to thermodynamics. Prerequisites: Basic knowledge of thermodynamics and chemical engineering thermodynamics.

Detailed Syllabus

Unit I **Lectures 6**
Review of fundamental principles: Review of thermodynamic laws, thermodynamic potentials, thermodynamic stability, and thermodynamic properties of pure substances.

Unit II **Lectures 10**
Thermodynamic properties of mixtures: Ideal-gas mixtures, ideal or Lewis mixtures - chemical potential and fugacity, partial molar properties, calculation of fugacity and fugacity coefficients, excess properties, concept of activity coefficient, correlative activity coefficient models.

Unit III **Lectures 10**
Phase equilibria: Fundamental VLE equation, VLE at low, moderate and high pressures, azeotropic data, multicomponent VLE, thermodynamic consistency test of VLE data, liquid-liquid equilibria, chemical reaction equilibria.

Unit IV **Lectures 6**
Intermolecular forces: Interactions between molecules, electrostatics and dipoles, potential-energy functions, molecular dynamics simulations.

Unit V **Lectures 6**
Statistical thermodynamics: Quantum mechanical aspects, thermodynamic probability and entropy, Boltzmann's distribution law, partition function, thermodynamic properties in terms of partition functions, partition functions of polyatomic molecules.

Text Books/Reference Books:

1. Prausnitz, J.M.; Lichtenthaler, R.N.; Gomes de Azevedo, E. "Molecular Thermodynamics of Fluid Phase Equilibria", Prentice Hall, 3rd Edition, 1998.
2. Sandler, S.I. "Chemical, Biochemical and Engineering Thermodynamics", Wiley, 4th Edition, 2006.
3. Rao, Y.V.C. "Chemical Engineering Thermodynamics", Universities Press, 1997.
4. Smith, J.M.; Van Ness, H.C.; Abbott, M.M. "Introduction to Chemical Engineering Thermodynamics", 7th Edition, 2005.
5. Koretsky, M.D. "Engineering and Chemical Thermodynamics", Wiley, 2004

Program Elective IV (b) (PD 2104)

Membrane Science and Technology

Teaching Scheme:
Lectures: 3 Periods/week ***Sessional Marks: 40***
University Examination: 3 hours. ***University Examination Marks: 60***

Unit I **Lectures 10**
Introduction and definitions: Separation concepts; diffusion across a thin film; terminology; driving force, biological vs. synthetic membranes, module, membrane, reactors.

Unit II **Lectures 10**
General transport models: Concentration and pressure gradients, solution-diffusion models, concentration polarization, membrane solute interactions.

Unit III **Lectures 10**
Reverse Osmosis (RO) and Nano Filtration (NF): Membrane selection procedures, polymer types, osmotic pressures, membrane fouling, design consideration and module, Optimum conditions, selective separation by NF, pre-treatment, application, economic consideration.

Unit IV **Lectures 12**
Membrane Reactor: Catalytic membranes, nonporous and porous inorganic membranes, equilibrium related reactions, membrane reactor for hazardous pollutant degradation, Bio functional membranes (Immobilized enzymes, covalent attachment methods, affinity chromatography, transport models); functionalized membranes, dialysis; artificial kidney.

Unit V
Membrane applications: Hybrid processes and novel applications, selected environmental applications for water reuse and material recovery, membrane flux & separation optimization.

Text/References:

- Mulder, M., Basic Principles of Membrane Technology, Kluwer Academic Publishers 1996
- Rautenbach, R., Albrecht, R., Membrane Processes, John Wiley, 1989.

Program Elective IV (c) (PD 2105)

Interfacial Science and Engineering

Teaching Scheme:
Lectures: 3 Periods/week ***Sessional Marks: 40***
University Examination: 3 hours. ***University Examination Marks: 60***

Objectives:
1. To familiarize students with various aspects of interfacial sciences and its associated phenomenon like emulsion, colloidal etc.
2. To enable students to understand the principles and kinetics of interface and their forces.
3. To introduce them to new trends used in the field of interfacial engineering.

Outcomes:
At the end of the course, the student will be able to**:**
1. Understand the basics of interfacial process and associated phenomenon.
2. Model the kinetics of interface and their forces.

Unit I **Lectures 6**
Introduction to the engineering of interfaces; Definitions of fluid-fluid and fluid-solid interfaces; Occurrence of interfaces in science and engineering; Overview of industrial applications of various interfacial phenomena; Colloidal materials; Properties of colloidal systems.

Unit II **Lectures 10**
Surface and interfacial tension; Theoretical methods for the calculation of surface and interfacial tension; Experimental techniques for the determination of equilibrium and dynamic tension; Shape of the surfaces: curvature and radius of curvature; Young-Laplace equation; Characterization of fluid-solid interfaces; Contact angle and wetting phenomena; Young-Dupré equation; Measurement of equilibrium and dynamic contact angles.

Unit III **Lectures 10**
Introduction to intermolecular and surface forces; van der Waals forces; Electrostatic double layer force, Adsorption at fluid-fluid and fluid-solid interfaces; Adsorption of surfactants; Gibbs and Langmuir monolayers; Gibbs adsorption equation; Surface equation of state; Surface pressure isotherm; Langmuir-Blodgett films and their applications

Unit IV **Lectures 10**

Emulsions: Preparation, characterization and applications; Ostwald ripening; Flocculation and coalescence; Microemulsions: characterization and properties; Stability of microemulsions; Foams: preparation, characterization and stability; Structure of foams.

Unit V **Lectures 6**
Application: General applications, Enhanced petroleum recovery, Novel fabrication of nanostructured particles, engineering surfaces and interfaces, Self-assembled and nanostructured biomimetic interfaces

Text Books/Reference Books:

1. Adamson, A. W. and Gast, A. P., Physical Chemistry of Surfaces, John Wiley, New York, 1997.
2. Ghosh, P., Colloid and Interface Science, PHI Learning Pvt. Ltd., New Delhi, 2009.
3. Hiemenz, P. C. and Rajagopalan, R., Principles of Colloid and Surface Chemistry, Marcel Dekker, New York, 1997.
4. Stokes, R. J. and Evans, D. F., Fundamentals of Interfacial Engineering, Wiley-VCH, New York, 1997.
5. Baszkin, A. and Norde, W., Physical Chemistry of Biological Interfaces, Marcel Dekker, New York, 2000.
6. Edwards, D. A., Brenner, H. and Wasan, D. T., Interfacial Transport Processes and Rheology, Butterworth-Heinemann, Boston, 1990.
7. Hunter, R. J., Foundations of Colloid Science, Oxford University Press, New York, 2005.
8. Israelachvili, J., Intermolecular and Surface Forces, Academic Press, London, 1992.
9. Slattery, J. C., Interfacial Transport Phenomena, Springer-Verlag, New York, 1990.

Program Elective IV (d) (PD 2106)

Nano Science and Technology

Teaching Scheme:
Lectures: 3 Periods/week ***Sessional Marks: 40***
University Examination: 3 hours. ***University Examination Marks: 60***

Objectives:
1. To familiarize students with various aspects of Nano-materials and its application in various fields.
2. To enable students to understand the principles and processes of prepare, characterization of nanostructured materials.
3. To introduce them to new trends used in the field of Nano-technology.

Outcomes:
At the end of the course, the student will be able to:
1. Categorize the use of nanomaterials in various field.
2. Analyze the formation Nano-materials
3. Investigate the nanostructure of materials through characterization techniques

Unit I **Lectures 8**
Introduction to nanotechnology: Background, definition, basic ideas about atoms and molecules, intermolecular forces used in supramolecular chemistry, self-assembly process in organic systems. Main supra molecular structure. physics of solid state, review of properties of Nanomaterials.

Unit II **Lectures 8**
Preparation of Nano materials: Preparation of Nanostructured Materials through bottom up and top down approach, Lithography, nanoscale lithography. Sol gel technique Molecular synthesis, Self-assembly, Polymerization,

Unit III **Lectures 8**
Characterization of Nano materials: Characterization of Nano-structured material (through AFM, SEM, TEM etc.). Cross-cutting, Nano materials in heat and mass transfer applications, Molecular electronics, Nanophotonics

Unit IV **Lectures 10**
Areas of Application of Nanotechnology: Energy storage, Production and Conversion. Agriculture productivity enhancement Water treatment and remediation. Disease diagnosis and screening. Drug delivery systems. Food processing and storage. Air pollution and remediation. Construction. Health monitoring. Vector and pest detection, and control. Biomedical applications.

Unit V **Lectures 8**
Emerging trends in applications of nanotechnology: Industrial applications of Nanotechnology: Development of carbon nanotube-based composites. Nanocrystalline silver Antistatic conductive coatings, nanometric powders, sintered ceramics, nanoparticle ZnO and TiO_2 for sun barrier products, other significant implications

Text Books/Reference Books:

1. S.M. Lindsay, "Introduction to Nanoscience", Oxford University Press, 2009.
2. S. K. Kulkarni, "Nanotechnology: Principles and Practices", Capital Publishing Company, 2007.
3. R. Kelsall, I. Hamley, M. Geoghegan, "Nanoscale Science and Technology", John Wiley & Sons, 2005.
4. G. Cao, "Nanostructures and Nanomaterials", Imperial College Press, London, 2004.
5. M.Ratner, D.Ratner, "A Gentle Introduction to Next Big Thing", Pearson Education 2005.

Program Elective IV (e) (PD 2107)

Process Plant Design & Flow Sheeting

Objectives:

1. Understanding of the scope, principles, norms, accountabilities and bounds of contemporary engineering practice in the specific discipline.
2. Application of established engineering methods to complex engineering problem solving.
3. Application of systematic engineering synthesis and design processes.

Outcomes: At the end of this course, students are able to:

1. Analyze, synthesize and design processes for manufacturing products commercially
2. Integrate and apply techniques and knowledge acquired in other courses such as thermodynamics, heat and mass transfer, fluid mechanics, instrumentation and control to design heat exchangers, plate and packed columns and engineering flow diagrams
3. Use commercial flow sheeting software to simulate processes and design process equipment
4. Recognize economic, construction, safety, operability and other design constraints
5. Estimate fixed and working capitals and operating costs for process plants

Detailed Syllabus

Unit I **Lectures 8**

Introduction: Basic concepts: General design considerations, Process design development,Layout of plant items, Flow sheets and PI diagrams, Economic aspects and Optimum design,Practical considerations in design and engineering ethics, Degrees of freedomanalysisininterconnected systems, Network analysis, PERT/CPM, Direct and Indirect costs,Optimumscheduling and crashing of activities.

Unit II **Lectures 8**

Hierarchy of chemical process design; Nature of process synthesis and analysis;Developinga conceptual design and flow sheet synthesis. Synthesis of reaction-separation systems; Distillationsequencing; Energy targets. Heat integration of reactors, distillationcolumns, evaporators and driers;Process change for improved heat integration. Heat and mass exchange networks and networkdesign.

Unit III **Lectures 8**

Flow-sheeting: Synthesis of flow sheet: Propositional logic and semantic equations,Deduction theorem, Algorithmic flow sheet generation using P-graph theory, Sequencing ofoperating units, Feasibility and optimization of flow sheet using various algorithms viz, SolutionStructure Generation (SSG), Maximal Structure Generation (MSG), Simplex, Branch-andbound etc.

Unit IV **Lectures 8**

Analysis of Cost estimation: Factors affecting Investment and production costs, Estimationof capital investment and total product costs, Interest, Time value of money, Taxes and Fixedcharges, Salvage value, Methods of calculating depreciation, Profitability, Alternativeinvestmentsand replacements.

Unit V **Lectures 8**

Optimum Design and Design Strategy: Break-even analysis, Optimum production rates inplant operation, Optimum batch cycle time applied to evaporator and filter press, Economic pipediameter, Optimum insulation thickness, Optimum cooling water flow rate and optimumdistillationreflux ratio.

Text Books/Reference Books:

1. Peters, M.A. and Timmerhaus, K.D., Plant Design and Economics for Chemical Engineers, McGraw Hill (2003).
2. Anil Kumar, Chemical Process Synthesis and Engineering Design, Tata McGraw Hill (1982).
3. Ulrich, G.D., A Guide to Chemical Engineering Process Design and Economics, John Wiley & Sons (1984).
4. Perry, R.H. and Green, D., Chemical Engineer's Handbook, McGraw-Hill (1997).

Program Elective V (a) (PD 2108)

Industrial Pollution Control

Teaching Scheme:
Lectures: 3 Periods/week ***Sessional Marks: 40***
University Examination: 3 hours. ***University Examination Marks: 60***

Objectives

1. To understand the importance of industrial pollution and its abatement
2. To study the underlying principles of industrial pollution control
3. To acquaint the students with case studies
4. Student should be able to design complete treatment system

Course Outcomes: At the end of the course, the student will be able to:

1. Recognize the causes and effects of environmental pollution
2. Analyze the mechanism of proliferation of pollution
3. Develop methods for pollution abatement and waste minimization
4. Design treatment methods for gas, liquid and solid wastes

Unit I **Lectures 06**
Industries & Environment
Industrial scenario in India - Industrial activity and Environment - Uses of Water by industry - Sources and types of industrial wastewater - Industrial wastewater and environmental impacts - Regulatory requirements for treatment of industrial wastewater - Industrial waste survey - Industrial wastewater generation rates, characterization and variables - Population equivalent - Toxicity of industrial effluents and Bioassay tests.

Unit II **Lectures 06**
Industrial Noise pollution Sources of noise pollution, characterization of noise pollution prevention& control of noise pollution, Factories Act 1948 for regulatory aspects of noise pollution.

Unit III **Lectures 10**
Air Pollutant Abatement
Air pollutants scales of concentration, lapse rate and stability, plume behavior, dispersion of air pollutants, atmospheric dispersion equation and its solutions, Gaussian plume models. Air pollution control methods, Source correction methods, Design concepts for pollution abatement systems for particulates and gases. Such as gravity chambers, cyclone separators, filters, electrostatic precipitators, condensation, adsorption and absorption, thermal oxidation and biological processes.

Unit IV **Lectures 10**
Waste water treatment processes
Design concepts for primary treatment, grid chambers and primary sedimentation basins, selection of treatment process flow diagram, elements of conceptual process design, design of thickner, biological treatment Bacterial population dynamics, kinetics of biological growth and its applications to biological treatment, process design relationships and analysis, determination of kinetic coefficients, activated sludge process. Design, trickling filter design considerations, advanced treatment processes,

Study of environment pollution from process industries and their abatement: Fertilizer, paper and pulp, inorganic acids, petroleum and petrochemicals, recovery of materials from process effluents.

Unit V **Lectures 10**

Solid waste and Hazardous waste management

Sources and classification, properties, public health aspects, Sanitary land fill design, Hazardous waste classification and rules, management strategies, Nuclear waste disposal Treatment methods – component separation, chemical and biological treatment, incineration, solidification and stabilization, and disposal methods, Latest Trends in solid waste management.

Text Books/Reference Books:

1. Rao C.S., “Environmental Pollution Control Engineering”, 2nd edition
2. Mahajan S.P., “Pollution Control in Process Industries”.
3. Nemerow N.L., “Liquid waste of industry- theories, Practices and Treatment”, Addison Wesley, New York, 1971
4. Weber W.J., “Physico-Chemical Processes for water quality control”, Wiley Interscience New York, 1969
5. Strauss W., “Industrial Gas Cleaning”, Pergamon, London, 1975
6. Stern A.C., “Air pollution”, Volumes I to VI, academic Press, New York, 1968
7. Peterson and Gross. E Jr., “Hand Book of Noise Measurement”, 7th Edn, 2003.
8. Antony Milne, “Noise Pollution: Impact and Counter Measures”, David & Charles PLC, 2009.

Program Elective V (b) (PD 2109)

AVANCED CHEMICAL REACTION ENGINEERING

Teaching Scheme:
Lectures: 3 Periods/week ***Sessional Marks: 40***
University Examination: 3 hours. ***University Examination Marks: 60***

Objective: The objective is to enable understanding of design of industrially important reactors both for homogeneous and heterogeneous chemical reactions on a commercial scale.
Prerequisite: Basics of chemical reaction engineering along with the fundamental knowledge of mass and heat transfer.

COURSE OUTLINE

Unit I: **Lectures 6**
Introduction to Chemical Reaction Engineering: chemical reactions, reaction order, molecularity, conversion, rate law and stoichiometry, elementary and non- elementary reactions, reaction rate constant, chemical equilibrium. Design of Isothermal Reactors: batch reactor, continuous stirred tank reactor (CSTR), plug-flow tubular reactor (PFTR), semi-batch reactor and recycle reactors.

Unit II: **Lectures 7**
Design of Non-isothermal Reactor: energy balance, reactors heat generation and removal, non-isothermal continuous flow reactor, energy balance in a CSTR and PFTR, adiabatic reactors, trajectories and phase-plane plots, trajectories of wall-cooled reactors.

Unit III: **Lectures 10**
Catalyst & Catalysis: catalytic reactions, reaction rates, rate equation for surface kinetics, porous catalysts, pore diffusion, and temperature dependence of catalytic reaction rates. Design of packed bed reactor for catalytic reactions

Unit IV: **Lectures 8**
Multiphase Reactors: introduction, types, and mass balance equations for multiphase reactors, interfacial surface area, mass transfer between phases, equilibrium between phases, membrane reactors, falling film reactor, bubble column reactors, trickle bed reactor, slurry reactor.

Unit V: **Lectures 8**
Models for Non-ideal Reactors: basics of non-ideal flow, residence time distribution (RTD) in ideal reactors; residence time distribution (RTD) in non-ideal reactors, Tanks-in-Series (T-I-S) model, Dispersion model, reaction and dispersion, Tanks-in-Series model versus Dispersion model.

Text Books/Reference Books:
1. Froment, G. F., Bischoff, K. B., and Wilde, J. D., "Chemical Reactor Analysis and Design", 3rd Edition, John Wiley & Sons, 2010.
2. Levenspiel, O., "Chemical Reaction Engineering", 3rd Edition, John Wiley & Sons, 2004.
3. Fogler, H. S., "Elements of Chemical Reaction Engineering" 3rd Edition, Prentice-Hall of India, 2005.
4. Schmidt, L. D., "The Engineering of Chemical Reactions", 2nd Edition, Oxford University Press, 2005.

Program Elective V (c) (PD 2110)

Modern concepts in Catalysis and Surface Phenomenon

Teaching Scheme:
Lectures: 3 Periods/week ***Sessional Marks: 40***
University Examination: 3 hours. ***University Examination Marks: 60***
Objectives
1. To give the students insight into advances in catalytic reaction engineering
2. To understand the mechanisms involved in catalytic reactions
3. To study the catalyst characterization techniques
4. To study the advanced industrial applications in catalysis
5. To understand the principles behind catalyst deactivation and study their models

Course Outcomes: At the end of the course, the student will be able to:
1. Understand the concepts of homogenous and heterogeneous catalysis, with specific examples.
2. Study reaction mechanisms and kinetics of homogenous and heterogeneous catalytic
3. reactions.
4. Familiarize with the characterization of catalysts
5. Understand the application and mechanisms of several types of catalysts in chemical
6. industry.

Unit ILectures 8
Introduction to Catalysis
Definition of Catalytic activity, Magnitude of Turnover Frequencies and Active Site Concentrations, Evolution of Important Concepts and Techniques in Heterogeneous Catalysis, Classification of Catalysts – Homogeneous, Heterogeneous, Biocatalysts, Dual Functional Catalysts, Enzymes, Solid Catalysts, Powder Catalysts, Pellets, Composition, Active Ingredients, Supportive materials, Catalysts Activation, Catalyst Deactivation.

Unit IILectures 8
Adsorption in Catalysis
Adsorption and its importance in Catalysis, Adsorption and potential energy curves, Surface Reconstruction, Adsorption Isotherms and Isobars, Dynamical Considerations, Types of Adsorption Isotherms and their Derivation from Kinetic Principles, Mobility at Surfaces, Kinetics of surface Reactions, Photochemistry on oxide and metallic surfaces, Characterization of the adsorbed molecules.

Unit IIILectures 8
Catalyst Characterization
Catalyst Characterization Methods – Their Working Principle and Applications – XRF, XRD, IR Spectroscopy, XPS, UPS, ESR, NMR; Infrared, Raman, NMR, Mossbauer and X-Ray Absorption spectroscopy, Surface Acidity and Toxicity, Activity, Life time, Bulk density, Thermal stability Crystal Defects, Peroviskites, Spinels, Clays, Pillared Clays, Zeolites

Unit IVLectures 8
Significance of Pore Structure and Surface Area
Importance of Surface Area and Pore Structure, Experimental Methods for Estimating Surface Area – Volumetric, Gravimetric, Dynamic Methods, Experimental Methods for Estimating Pore Volume and Diameter – Gas Adsorption and Mercury Porosimeter Method, Models of

the Pore Structure – Hysteresis Loops, Geometric Models, Wheeler's Model, Dusty Gas Model, Random Pore Model, Diffusion in Porous Catalysts – Effective Diffusivity, Knudsen Diffusion, Effect of Intraparticle Diffusion, Non-isothermal Reactions in Pores, Diffusion Control.

Unit VLectures 8

Industrial applications– Case Studies

Industrial processes involving heterogeneous solid catalyst: Synthesis of Methanol, FiscerTropsch Catalysis, Synthesis of Ammonia, Automobile Exhaust Catalysts and Catalyst Monolith, Photocatalytic Breakdown of Water and the Harnessing of Solar Energy.

Contribution of homogeneous catalytic process in chemical industry: Oxidations of Alkenes such as production of acetaldehyde, propylene oxide etc., Polymerization such as production of polyethylene, polypropylene or polyester production.

Text Books/References Books

1. Emmett, P.H. - "Catalysis Vol. I and II, Reinhold Corp.", New York, 1954
2. Smith, J.M. - "Chemical Engineering Kinetics ", McGraw Hill, 1971
3. Thomas and Thomas - "Introduction to Heterogeneous Catalysts ", Academic Press, London 1967
4. Piet W.N.M. van Leeuwen, Homogeneous catalysis: Understanding the Art, Springer, 2004
5. Piet W.N.M. van Leeuwen, and John C. Chadwick, Homogeneous catalysis: Activity-stability–deactivation, Wiley, VCH, 2011.

Program Elective V (d) (PD 2111)

Process Design and Synthesis

Teaching Scheme:
Lectures: 3 Periods/week ***Sessional Marks: 40***
University Examination: 3 hours. ***University Examination Marks: 60***

Objectives:
1. To understand the systematic approaches for the development of conceptual chemical process designs
2. To learn the advances in problem formulation and software capabilities which offer the promise of a new generation of practical process synthesis techniques based directly on structural optimization.
3. Learning chemical process synthesis, analysis, and optimization principles
4. Product design and development procedure and Process life cycle assessment.

Outcomes: At the end of the course, the student will be able to:
1. Analyze alternative processes and equipment
2. Synthesize a chemical process flow sheet that would approximate the real process
3. Design best process flow sheet for a given product
4. Perform economic analysis related to process design and evaluate project profitability

Unit I: Lectures 8
Introduction
Introduction to fundamental concepts and principles of process synthesis and design and useof flowsheet simulators to assist process design. Process Flow sheet Models: An Introductionto Design,Chemical process synthesis, analysis and optimization. Introduction to commercial process designsoftware such as HYSYS, Aspen plus etc., Chemical Process (reactor, heat exchanger, distillationetc) analysis using commercial software

Unit II: Lectures 8
Product designand developments
Process engineering economics and project evaluation Life Cycle Assessments of process:Fromdesign to product development, Engineering Economic Analysis of ChemicalProcesses, Projectcosting and performance analysis, Environmental concerns, greenengineering, Engineering ethics,Health and safety.

Unit III: Lectures 8
Reactor Networks
Geometry of mixing and basic reactor types, The Attainable Region (AR) approach, AR inhigherdimensions & for other processes, Reactive Separation processes, Fundamentalbehaviour andproblems, Separation through reactions. Reactive Residue Curve Maps

Unit IV: Lectures 8
Synthesis of Separation Trains
Criteria for selection of separation methods, select ion of equipment**:** Absorption, Liquid-liquidextraction Membrane separation, adsorption, leaching, drying, crystallization, Ideal distillation -Column and sequence fundamentals, Sharp splits & sequencing Phase diagrams for 2, 3 and 4components, Feasibility and vapor of rates for single columns, Residue curve

basics, Non-idealDistillation - Azeotropic systems; detecting binary azeotropes, Residue curve maps for azeotropicsystems, Topological analysis, Feasibility for single azeotropic columns,Binary VLLE and pressureswingseparation, Non-ideal distillation synthesis. Equipment sequencing: VLE + VLLE, DetailedResidue Curve Maps, Residue curve maps:Interior structure

Unit V: Lectures 8
Heat Exchanger Network Synthesis
Minimum heating and cooling requirements, Minimum Energy Heat Exchanger Network,Loops andPaths, Reducing Number of Exchangers, HENS basics & graphics, The pinch point approach, StreamSplitting, Performance targets, trade-off & utilities, Heat & power integration

Text Books /Reference Books

1. Douglas, J. "Conceptual Design of Chemical Processes",New York, NY: McGraw-HillScience/Engineering/Math, 1988. ISBN: 0070177627.
2. Seider, W. D., J. D. Seader, and D. R. Lewin. "Product and Process Design Principles:
3. Synthesis, Analysis, and Evaluation",. *2*nd ed. New York, NY: Wiley, 2004. ISBN:0471216631.
4. Richard Turton, Richard C. Bailie, Wallace B. Whiting, Joseph A. Shaeiwitz., "Analysis,
5. Synthesis, and Design of Chemical Processes", 2nd Edition, 2002, Prentice Hall ISBN-10: 0-
6. 13-064792-6
7. Biegler L.T., Grossmann I.E. and Westerberg A.W., "Systematic Methods of ChemicalProcess Design", Prentice Hall, 1997.

Program Elective V (e) (PD 2112)

Industrial Safety

Teaching Scheme:

Lectures: 3 Periods/week ***Sessional Marks: 40***

University Examination: 3 hours. ***University Examination Marks: 60***

Unit I: Lectures 8

Industrial safety: Accident, causes, types, results and control, mechanical and electricalhazards, types, causes and preventive steps/procedure, describe salient points of factories act 1948 for health and safety, wash rooms, drinking water layouts, light, cleanliness, fire, guarding, pressure vessels, etc, Safety color codes. Fire prevention and firefighting, equipment and methods.

Unit II: Lectures 8

Fundamentals of maintenance engineering: Definition and aim of maintenance engineering,Primary and secondary functions and responsibility of maintenance department, Types of maintenance, Types and applications of tools used for maintenance, Maintenance cost & its relation with replacement economy, Service life of equipment.

Unit III: Lectures 8

Wear and Corrosion and their prevention: Wear- types, causes, effects, wear reductionmethods, lubricants-types and applications, Lubrication methods, general sketch, working and applications, (i) Screw down grease cup, (ii). Pressure grease gun, (iii). Splash lubrication, (iv). Gravity lubrication, (v). Wick feed lubrication (vi). Side feed lubrication, (vii). Ring lubrication, Definition, principle and factors affecting the corrosion. Types of corrosion, corrosion prevention methods.

Unit IV: Lectures 8

Fault tracing: Fault tracing-concept and importance, decision treeconcept, need andapplications, sequence of fault-finding activities, show as decision tree, draw decision tree for problems in machine tools, hydraulic, pneumatic,automotive, thermal and electrical equipment’s like, I. Any one machine tool, ii. Pump iii. Air compressor, iv. Internal combustion engine, v. Boiler, vi. Electrical motors, Types of faults in machine tools and their general causes.

Unit V: Lectures 8

Periodic and preventive maintenance: Periodic inspection-concept and need, degreasing,cleaning and repairing schemes, overhauling of mechanical components, overhauling of electrical motor, common troubles and remedies of electric motor, repair complexities and its use, definition, need, steps and advantages of preventive maintenance. Steps/procedure for periodic and preventive maintenance of: I. Machine tools, ii. Pumps, iii. Air compressors, iv. Diesel generating (DG) sets, Program and schedule of preventive maintenance of mechanical and electrical equipment, advantages of preventive maintenance. Repair cycle concept and importance

Text Books/Reference Books:

1. Maintenance Engineering Handbook, Higgins & Morrow, Da Information Services.
2. Maintenance Engineering, H. P. Garg, S. Chand and Company.
3. Pump-hydraulic Compressors, Audels, Mcgrew Hill Publication.
4. Foundation Engineering Handbook, Winterkorn, Hans, Chapman & Hall London.

Open Elective I (a) (PD 2113)

Business Analytics

Teaching Scheme:

Lectures: 3 Periods/week — ***Sessional Marks: 40***

University Examination: 3 hours. — ***University Examination Marks: 60***

Course objective:

1. Understand the role of business analytics within an organization.
2. Analyze data using statistical and data mining techniques and understand relationships between the underlying business processes of an organization.
3. To gain an understanding of how managers use business analytics to formulate and solve business problems and to support managerial decision making.
4. To become familiar with processes needed to develop, report, and analyze business data.
5. Use decision-making tools/Operations research techniques.
6. Mange business process using analytical and management tools.
7. Analyze and solve problems from different industries such as manufacturing, service, retail, software, banking and finance, sports, pharmaceutical, aerospace etc.

Course Outcomes:

1. Students will demonstrate knowledge of data analytics.
2. Students will demonstrate the ability of think critically in making decisions based on data and deep analytics.
3. Students will demonstrate the ability to use technical skills in predicative and prescriptive modeling to support business decision-making.
4. Students will demonstrate the ability to translate data into clear, actionable insights.

Detailed Syllabus

Unit I: Lectures 8

Business analytics: Overview of Business analytics, Scope of Businessanalytics, Business Analytics Process, Relationship of Business Analytics Process and organization, competitive advantages of Business Analytics. Statistical Tools: Statistical Notation, Descriptive Statistical methods, Review of probability distribution and data modelling, sampling and estimation methods overview.

Unit II: Lectures 8

Trendiness and Regression Analysis: Modelling Relationships and Trends in Data, simple Linear Regression. Important Resources, Business Analytics Personnel, Data and models for Business analytics, problem solving, Visualizing and Exploring Data, Business Analytics Technology.

Unit III: Lectures 7

Organization Structures of Business analytics, Team management, Management Issues, Designing Information Policy, Outsourcing, Ensuring, Data Quality, measuring contribution of Business analytics, Managing Changes.Descriptive Analytics, predictive analytics, predicative Modelling, Predictive analytics analysis, Data Mining, Data Mining Methodologies, Prescriptive analytics and its step in the business analytics Process, Prescriptive Modelling, nonlinear Optimization.

Unit IV: Lectures 7

Forecasting Techniques: Qualitative and Judgmental Forecasting, Statistical Forecasting Models,Forecasting Models for Stationary Time Series,Forecasting Models for Time Series with a Linear Trend, Forecasting Time,Series with Seasonality, Regression Forecasting with Casual Variables,Selecting Appropriate Forecasting Models. Monte Carlo Simulation and Risk Analysis: Monte Carle Simulation Using Analytic Solver Platform, New-Product Development Model, Newsvendor Model, Overbooking Model, Cash Budget Model.

Unit V: Lectures 10

Decision Analysis: Formulating Decision Problems, Decision Strategies with the without Outcome Probabilities, Decision Trees, the Value of Information, Utility and Decision Making.

Recent Trends in: Embedded and collaborative business intelligence, Visual data recovery, Data Storytelling and Data journalism.

Text Books/Reference Books:

1. Business analytics Principles, Concepts, and Applications by Marc J. Schniederjans, Dara G. Schniederjans, Christopher M. Starkey, Pearson FT Press.
2. Business Analytics by James Evans, persons Education

Open Elective I (b) (PD 2114)

Operational Research

Teaching Scheme:
Lectures: 3 Periods/week — ***Sessional Marks: 40***
University Examination: 3 hours. — ***University Examination Marks: 60***

Course objectives:

1. Application of various optimization techniques in chemical engineeringproblems.
2. To learn about constrained and unconstrained optimization problems.
3. To know the use of optimization in real life problems.

Course outcomes:
At the end of the course, the student will be able to**:**

1. Solving linear and nonlinear optimization problems.
2. Categorizing the use of optimization techniques in various fields.

Unit I — **Lectures 6**
Linear programming problem: Basic concepts in linear programming, mathematical formulation of L.P.P, graphical solution, simplex method, The big-M method, two phase method, degeneracy in simplex method, dual simplex method, integer programming.

Unit II — **Lectures 6**
Non-linear optimization: Introduction to constrained and unconstrained optimization problems –Newton method, secant method, Region elimination method, Lagrange multiplier method.

Unit III — **Lectures 8**
Transportation problem: North – West comer rule and Vogel's approximation method to find optimal basic feasible solution, Modi method.

Unit IV — **Lectures 8**
Assignment problem: Characteristics of M/M/1/∞, M/M/1/K and M/M/c/∞ queuing models in the steady-state. Introduction to the inventory problem: Deterministic and probabilistic models.

Unit V — **Lectures 8**
Introduction to network construction: CPM/PERT techniques, critical path method(CPM),determination of critical path(Labelling Method),the project evaluation and review Technique(PERT), probability considerations in PERT, distinction between PERT and CPM, project cost, time-cost optimization algorithm.

Text Books/Reference Books

1. T.F. Edgar and D. M. Himmelblau, “Optimization of Chemical Processes”, 2nd Edition, McGraw Hill, 2001.
2. S. R. Singiresu, “Engineering Optimization: Theory and Practice”, 4th Edition, John Wiley & Sons Ltd., 2009.

3. M. C. Joshi and K. M. Moudgalya, “Optimization: Theory and Practice”, Alpha Science International Limited, 2004.
4. K. Deo, “Optimization Techniques”, Wiley Eastern, 1995.
5. R. Panneerselvam, “Operation Research”, Second edition, PHI Learning private Ltd., New Delhi, India, 2006.
6. P. K. Gupta and D.S. Hira, “Problems in Operations Research (Principles andSolutions)”, S.Chand and company Ltd. New Delhi, India, 2008.

Open Elective I (c) (PD 2115)

Cost Management of Engineering Projects

Teaching Scheme:
Lectures: 3 Periods/week ***Sessional Marks: 40***
University Examination: 3 hours. ***University Examination Marks: 60***

Syllabus Contents:

Unit I **Lectures 6**

Introduction and Overview of the Strategic Cost Management Process

Unit II **Lectures 6**

Cost concepts in decision-making; Relevant cost, Differential cost, Incremental cost and Opportunity cost. Objectives of a Costing System; Inventory valuation; Creation of a Database for operational control; Provision of data for Decision-Making.

Unit III **Lectures 12**

Project: meaning, Different types, why to manage, cost overruns centers, various stages of projectexecution: conception to commissioning. Project execution as conglomeration of technical and non-technical activities. Detailed Engineering activities. Pre project execution main clearances and documents Project team: Role of each member. Importance Project site: Data required with significance. Project contracts. Types and contents. Project execution Project cost control. Bar charts and Network diagram. Project commissioning: mechanical and process

Unit IV **Lectures 10**

Cost Behavior and Profit Planning Marginal Costing; Distinction between Marginal Costing and Absorption Costing; Break-even Analysis, Cost-Volume-Profit Analysis. Various decision-making problems. Standard Costing and Variance Analysis. Pricing strategies: Pareto Analysis. Target costing, Life Cycle Costing. Costing of service sector. Just-in-time approach, Material Requirement Planning, Enterprise Resource Planning, Total Quality Management and Theory of constraints. Activity-Based Cost Management, Bench Marking; Balanced Score Card and Value-Chain Analysis. Budgetary Control; Flexible Budgets; Performance budgets; Zero-based budgets. Measurement of Divisional profitability pricing decisions including transfer pricing.

Unit V **Lectures 6**

Quantitative techniques for cost management, Linear Programming, PERT/CPM, Transportation problems, Assignment problems, Simulation, Learning Curve Theory.

Text Books/Reference Books:

1. Cost Accounting A Managerial Emphasis, Prentice Hall of India, New Delhi
2. Charles T. Horngren and George Foster, Advanced Management Accounting
3. Robert S Kaplan Anthony A. Alkinson, Management & Cost Accounting
4. Ashish K. Bhattacharya, Principles & Practices of CostAccounting A. H. Wheeler publisher
5. N.D. Vohra, Quantitative Techniques in Management, Tata McGraw Hill Book Co. Ltd.

Open Elective I (d) (PD 2116)

Composite Materials

Teaching Scheme:

Lectures: 3 Periods/week ***Sessional Marks: 40***
University Examination: 3 hours. ***University Examination Marks: 60***

Syllabus Contents:
Unit I **Lectures 8**
Introduction:
Definition – Classification and characteristics of Composite materials.Advantages and application of composites. Functional requirements of reinforcement and matrix. Effect of reinforcement (size, shape, distribution, volume fraction) on overall composite performance.

Unit II **Lectures 8**
Reinforcements:
Preparation-layup, curing, properties and applications of glassfibers, carbon fibers, Kevlar fibers and Boron fibers. Properties and applications of whiskers, particle reinforcements. Mechanical Behavior of composites: Rule of mixtures, Inverse rule of mixtures. Isostrain and Iso-stress conditions.

Unit III **Lectures 8**
Manufacturing of Metal Matrix Composites:
Casting – Solid State diffusion technique,Cladding – Hot isostatic pressing. Properties and applications. Manufacturing of Ceramic Matrix Composites: Liquid Metal Infiltration – Liquid phase sintering. Manufacturing of Carbon – Carbon composites: Knitting, Braiding, Weaving. Properties and applications.

Unit IV **Lectures 8**
Manufacturing of Polymer Matrix Composites:
Preparation of Moulding compounds andprepregs – hand layup method – Autoclave method – Filament winding method – Compression moulding – Reaction injection moulding. Properties and applications.

Unit V **Lectures 8**
Strength:
Laminar Failure Criteria-strength ratio, maximum stress criteria, maximumstrain criteria, interacting failure criteria, hygrothermal failure. Laminate first play failure-insight strength; Laminate strength-ply discount truncated maximum strain criterion; strength design using caplet plots; stress concentrations.

TEXT BOOKS/ Reference Books:

1. Material Science and Technology – Vol 13 – Composites by R.W.Cahn – VCH, West Germany.
2. Materials Science and Engineering, An introduction. WD Callister, Jr., Adapted by R. Balasubramaniam, John Wiley & Sons, NY, Indian edition, 2007.
3. Hand Book of Composite Materials-ed-Lubin.
4. Composite Materials – K.K.Chawla.
5. Composite Materials Science and Applications – Deborah D.L. Chung.
6. Composite Materials Design and Applications – Danial Gay, Suong V. Hoa, and Stephen W. Tasi.

Open Elective I (e) (PD 2117)

Computational Fluid Dynamics

Teaching Scheme:

Lectures: 3 Periods/week ***Sessional Marks: 40***
University Examination: 3 hours. ***University Examination Marks: 60***

Objectives
1. To make students understand the governing equations of fluid dynamics and their derivation from laws of conservation
2. To develop a good understanding in computational skills, including discretisation, accuracy and stability.
3. To acquaint the students with a process of developing a mathematical and geometrical model of flow, applying appropriate boundary conditions and solving system of equations.

Outcomes: At the end of the course, the students will be able to:
1. Understand the basic principles of mathematics and numerical concepts of fluid dynamics.
2. Develop governing equations for a given fluid flow system.
3. Adapt finite difference techniques for fluid flow models.
4. Apply finite difference method for heat transfer problems.
5. Solve computational fluid flow problems using finite volume techniques.
6. Get familiarized to modern CFD software used for the analysis of complex fluid-flow systems.

Unit I **Lectures 8**
Introduction to Fluid Dynamics
Concepts of Fluid Flow, Pressure distribution in fluids, Reynold's transport theorem, Integral form ofconservation equations, Differential form of conservation equations, Different Types of Flows, Eulerand Navier Stokes equations, Properties of supersonic and subsonic flows, Flow characteristics overvarious bodies. Philosophy of CFD, Governing equations of fluid dynamics and there physicalmeaning, Mathematical behaviour of governing equations and the impact on CFD simulations, SimpleCFD techniques and CFL condition. Numerical Methods in CFD:Finite Difference, Finite Volume,and Finite Element, Upwind and downwind schemes, Simple and Simpler schemes, Higher ordermethods, Implicit and explicit methods, Study and transient solutions

Unit II **Lectures 8**
Grid Generation
Basic theory of structured grid generation, Surface grid generation, Mono block, multi block, hierarchical multi block, Moving and sliding multiblock, Grid clustering and gridenhancement.Basic theory of unstructured grid generation, advancing front, Delaunay triangulation andvariouspoint insertion methods, Unstructured quad and hex generation, grid-based methods, variouselements in unstructured grids, Surface mesh generation, Surface mesh repair, Volume gridgeneration, Volume mesh improvement, mesh smoothing algorithms, grid clustering and qualitychecks for volume mesh. Adaptive, Moving and Hybrid Grids, need for adaptive and, moving grids,Tet, pyramid, prism, and hex grids, using various elements in combination

Unit III **Lectures 8**

Turbulence and its Modelling

Transition from laminar to turbulent flow, Effect of turbulence on time-averaged NavierStokesequations, Characteristics of simple turbulent flows, Free turbulent flows, Flat plateboundary layerand pipe flow, Turbulence models, Mixing length model,The k-e model, Reynolds stress equationmodels, Algebraic stress equation models.

Unit IV **Lectures 8**

Chemical Fluid Mixing Simulation

Stirred tank modeling using the actual impeller geometry, Rotating frame model, The MRF ModelSliding mesh model, Snapshot model, Evaluating Mixing from Flow Field Results,IndustrialExamples

Unit V **Lectures 8**

Post-Processing of CFD results

Contour plots, vector plots, and scatter plots, Shaded and transparent surfaces, Particletrajectoriesand path line trajectories, Animations and movies, Exploration and analysis of data.

Text Books/Reference Books

1. Anderson John D., “Computational Fluid Dynamics: The Basics with Applications”, Mc Graw Hill, 1995
2. Ranade V.V., “Computational Flow Modeling for Chemical Reactor Engineering”, Process
3. Engineering Science, Volume 5, 2001
4. Knupp Patrick and Steinberg Stanly, “Fundamentals of Grid Generation”, CRC Press, 1994
5. Wilcox D.C., “Turbulence Modelling for CFD”, 1993
6. Wesseling Pieter, “An Introduction to Multigrid Methods”, John Wiley & Sons, 1992
7. Thompson J.F., Warsi Z.U.A. and Mastin C.W., “Numerical Grid Generation: Foundations
8. and Applications”, North Holland, 1985
9. Patankar S.V., “Numerical Heat Transfer and Fluid Flow”, McGraw-Hill,1981
10. Gatski Thomas B., Hussaini M. Yousuff and Lumley John L., “Simulation and Modelling of
11. Turbulent Flows”, Oxford University Press, 1996
12. Laney, C. B., “Computational Gas Dynamics”, Cambridge Uni. Press, 1998.

Lab- III (PD 2201)
Advanced Chemical Reaction Engineering Laboratory

Lectures: 3 Periods/week ***Sessional Marks:50***
External Examination Marks: 50

List of Experiments

Sl.	Name of Experiment	Aim
1.	Interpretation of Batch Reactor data	To study the interpretation of Batch Reactor Data
2.	Absorption Kinetics	Adsorption of different concentrations of acetic acid on the surface of activatedcharcoal.
3.	Batch Reactor for irreversible reaction	To study batch reactor kinetics for Acetic acid–Methanol and find the value of rate constant
4.	Saponification of Ethyl Acetate	To determine the order of saponification of ethyl acetate in dilute aqueous reaction and toreport the value of the reaction rate constant.
5.	RTD	To determine RTD of 50 mL burette
6.	Batch Reactor for irreversible reaction	To study batch reactor kinetics for ethyl acetate - NaOH and find the value of rate constant.
7.	Batch Reactor for irreversible reaction-2	To determine the order and rate constant of esterification reaction
8.	Through Virtual Labs	Reaction kinetic studies in a batch reactor
9.	Through Virtual Labs	Reaction kinetic studies in a mixed flow reactor
10.	Through Virtual Labs	Reaction kinetic studies in a plug flow reactor

Lab- IV (PD 2202)
Advanced Process Dynamics Laboratory

Lectures: 3 Periods/week ***Sessional Marks:50***
External Examination Marks: 50

List of Experiments

1. Temperature Control System
2. Flow Controller System
3. Level Controller System
4. Pressure Controller System
5. Study and performance of ON/OFF temperature controller
6. Determination of lag coefficient of Cr-Ni Thermocouple immersed in water bath
7. Study and operation of temperature transmitter
8. Study and operation of whirling type hygrometer
9. Study and operation of dead weight pressure gauge tester