Course Curriculum

M. Tech

IN

CHEMICAL ENGINEERING

2016

Department of Chemical Engineering

JAYPEE UNIVERSITY OF ENGINEERING & TECHNOLOGY

A-B ROAD, RAGHOGARH, DIST. GUNA-473226 MP, INDIA

2 year M. Tech Course Curricula for Chemical Engineering							
M. Tech I semester							
S. N.	**Course Code**	**Course Title**	**Type**	**L**	**T**	**P**	**Credits**
1.	14M11CL111	Advanced Transport Phenomena	Core	3	0	0	3
2.	14M11CL112	Process Modelling and Optimization	Core	3	0	0	3
3.	14M11CL113	Chemical Reaction Engineering	Core	3	0	0	3
4.	14M11CL114	Advanced Separation Processes - I	Core	3	0	0	3
5.	14M1GCL13x	Elective-I	Elective	3	0	0	3
6.	14M17CL171	Chemical Reaction Engineering Laboratory	Core	0	0	4	2
			Sub Total				**17**

2 year M. Tech Course Curricula for Chemical Engineering							
M. Tech II semester							
S. N.	**Course Code**	**Course Title**	**Type**	**L**	**T**	**P**	**Credits**
1.	14M11CL211	Advanced Separation Processes - II	Core	3	0	0	3
2.	14M11CL212	Advanced Thermodynamics	Core	3	0	0	3
3.	14M11CL213	Environmental Eng. & Waste management	Core	3	0	0	3
4.	14M11CL214	Process Dynamics & Control	Core	3	0	0	3
5.	14M1GCL23x	Elective II	Elective	3	0	0	3
6.	14M19CL291	Seminar / Term Paper	Core	0	0	4	2
			Sub Total				**17**

2 year M. Tech Course Curricula for Chemical Engineering							
M. Tech III semester							
S. N.	**Course Code**	**Course Title**	**Type**	**L**	**T**	**P**	**Credits**
1.	14M1GCL33x	Elective-III	Elective	3	0	0	3
2.	14M1GCL33x	Elective-IV	Elective	3	0	0	3
3.	14M19CL391	Project Seminar	Core	0	0	4	2
4.	14M19CL392	Thesis	Core	0	0	24	12
			Sub Total				**20**

2 year M. Tech Course Curricula for Chemical Engineering							
M. Tech IV semester							
S. N.	**Course Code**	**Course Title**	**Type**	**L**	**T**	**P**	**Credits**
1.	14M1GCL43x	Elective-V	Elective	3	0	0	3
2.	14M1GCL43x	Elective-VI	Elective	3	0	0	3
3.	14M19CL491	Project Seminar	Core	0	0	4	2
4.	14M19CL492	Thesis	Core	0	0	28	14
			Sub Total				**22**
			Total Credits =				**76**

Notes:

1. Thesis ** to be continued from III Semester
2. Final evaluation of the dissertation will be based on the cumulative performance in all III and IV Semesters
3. It is desirable to have one publication from the dissertation

LIST OF ELECTIVES

S. No.	Elective No.	Code	Title
1	Elective I	14M1GCL131	Wastewater Treatment
2		14M1GCL132	Air Pollution Control
3		14M1GCL133	Cleaner Technology
4	Elective II	14M1GCL231	Process Plant Simulation
5		14M1GCL232	Colloid and Interfacial Engineering
6		14M1GCL233	Advances in Process Control
7		14M1GCL234	Applied Optimization & Operations Research
8	Elective III	14M1GCL331	Petroleum Refinery Operations
9		14M1GCL333	Polymer Science & Engineering
10		14M1GCL334	Combustion Processes
11		14M1GCL335	Environmental Management
12	Elective IV	14M1GCL332	Fluidization Engineering
13		14M1GCL336	Multiphase Contactors
14		14M1GCL337	Catalysis & Surface Chemistry
15		14M1GCL338	Reaction Engineering in dispersed phase systems
16	Elective V	14M1GCL431	Process Engineering
17		14M1GCL432	Conceptual Design of selected separation processes.
18		14M1GCL433	Safety & Hazards analysis and assessment
19		14M1GCL434	Nanotechnology and applications
20	Elective VI	14M1GCL435	Advanced Process Synthesis
21		14M1GCL436	Bioprocess principles
22		14M1GCL437	Bio separations

SCHEME OF EVALUATION FOR THEORY/PRACTICAL SUBJECTS

EVALUATION SCHEME IN THEORY SUBJECTS

MARKS DISTRIBUTION	DURATION	WEIGHTAGE	SYLLABUS
Test – I	1 hr.	15	Portions Covered up-to T1
Test – II	1 hr. and 30 Mins	25	1/3 Portion from T1 and rest taught after T 1
Test – III	2 hrs.	35	1/3 Portions from T1 and T2 and rest taught after T 2
Continuous evaluation		25	

DISTRIBUTION OF MARKS IN CONTINUOUS EVALUATION

MARKS DISTRIBUTION	WEIGHTAGE
Assignments and Seminars (4)	2
Materials Gathered	1
Presentation	1
Structured Quizzes(6)	6
Tutorial(10)	
Class work	5
Home work	5
Attendance (5)	
80% attendance	1
83% attendance	2
86% attendance	3
89% attendance	4
90% attendance and above	5

EVALUATION SCHEME IN PRACTICAL SUBJECTS

COMPONENT	SUB-WEIGHTAGE	WEIGHTAGE
Day-to-Day work - Attendance & discipline in Lab - Conduct of experiments etc. - Lab record	15 % 40 % 15 %	70 %
Mid-semester lab viva / test (P-1)		15 %
End-semester lab viva / test (P-2)		15 %

EVALUATION SCHEME IN PROJECT/THESIS WORK

COMPONENT	SUB-WEIGHTAGE	WEIGHTAGE
Evaluation by Project Guide / Research Advisor - Attendance & Sincerity - Plan of work - Evaluation of work	05 % 10 % 20 %	35 %
First Evaluation	-	15 %
Second Evaluation	-	15 %
Third (Final) Evaluation	-	20 %
Evaluation of Project Report / Thesis	-	15 %

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4.	14M11CL114	Advanced Separation Processes - I	Core	3	0	0	3
5.	14M1GCL13x	Elective-I	Elective	3	0	0	3
6.	14M17CL171	Chemical Reaction Engineering Laboratory	Core	0	0	4	2
			Sub Total				**17**

Course Description

Title of Course: Advanced Transport Phenomena **Course Code: 14M11CL111**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

The main aim of the course is to give an introduction to the mathematical foundation required for the analysis of fluid flow, heat transfer and mass transfer. The emphasis of the course will be on formulation of a given physical problem in terms of appropriate conservation equations, and obtaining a physical understanding of the associated phenomena.

Course Outcome

At the end of this course students should able to analyse any transport related problem mathematically and predict the physical behaviour of the process.

Course Contents

UNIT 1: Preliminaries **&** Introduction

Vector and tensor algebra: Geometric view point, addition of vectors, multiplication by scalar, scalar product, cross product,

analytical view point: kronecker delta, alternative unit tensor for cross product, cross product between two unit vector, vector operations in terms of components, vector addition , multiplication by scalar, scalar product between vectors, vectors product, identities for ε_{ijk} .

Vector Differential operations: Del operator, gradient of scalar, divergence of a vector, curl of a vector, Laplacian of a scalar, material derivative of a scalar.

Tensors: second order tensor, dyadic product, unit tensor, transpose of tensor, addition, dot product, double dot product, vector product, divergence of a tensor, trace, determinant.

Integral Theorems: Divergence theorem, curl theorem, Liebnitz rule.

Cylindrical coordinates: Del operator in cylindrical coordinates, derivatives of unit vectors,

Kinematics: Eulerian & Lagrangian view point, relationship between Eulerian and Lagrangian view points, Reynolds transport theorem, Motion near a point, relative velocity, vorticity tensor,

UNIT 2: Fluid Mechanics

Governing equations: conservation of mass, continuity equation, conservation of linear momentum, conservation of angular momentum, stress tensor, Cauchy's 1^{st} & 2^{nd} laws, Navier-Stokes equations, unidirectional flows, flow down an inclined surface, flow of generalized Newtonian fluid in cylindrical tube, flow with central plug region, tangential annular flow, velocity in the limit of narrow gap, flow due to wall suddenly set in motion, unsteady flow between parallel plates, two dimensional flows, stream function, stream lines, dimensional analysis approximation, dimensionless governing equations, creeping flow , velocity of particle falling from rest, flow in slow varying channels, in-viscid flow, potential flow past a cylinder, boundary layer theory, flow past a flat plate, converging flow, diverging flow, turbulent flow, transition to turbulence, turbulence models

UNIT 3: Heat Transfer

Governing equations: energy balance equations, conservation of energy law, heat flux at any point, mechanical energy balance, constitutive equations for conduction, boundary conditions, steady state conduction through a composite wall, temperature profile in an electric wire, unsteady state conduction in a slab, heat conduction with generation in a slab, viscous dissipation, heat transfer from a cooling fin, forced convection in a pipe, macroscopic energy balance, free convection, free convection between vertical parallel plates, free convection near a heated vertical plate, free convection heat transfer from a vertical plate, dimensionless parameter for heat transfer, Radiation.

UNIT 4: Mass Transfer:

Governing equations: species mass balance, Concentration, velocities and mass fluxes, constitutive equations, boundary conditions, Complete solutions: diffusion through a stagnant film, diffusion of gas with heterogeneous reaction, diffusion with homogeneous chemical reaction, diffusion into a falling liquid film, diffusion and reaction in a spherical droplet, diffusion and reaction in a porous catalyst pellet, Simultaneous heat and mass transfer, condensation in the presence of non-condensable gases.

Text Book

1. Bird, R.B., Stewart, W.E. and Lightfoot, E. N., 2002, “Transport Phenomena”, 2nd Ed., John Wiley & Sons, New York

Reference Books

1. Slattery, J.C., 1981, “Momentum, Heat and Mass Transfer”, Krieger Pub.
2. Batchelor, G.K., 1967, “Introduction to Fluid Dynamics”, Cambridge Uni. Press
3. Pritchand, P. J., Fox, R. W., McDonald, A. T. and Leylegian, J. C.,2010, “Fox and McDonald’s Introduction to Fluid Mechanics” , 8th Ed., John Wiley & Sons
4. Munson, R. B., Young, D.P. and Okiishi, T. H, Huebsch, W. W., 2008, “Fundamentals of Fluid Mechanics”, 6th Ed., John Wiley & Sons, New York
5. Tosun, I., 2007, “Modelling in Transport Phenomena- A Conceptual Approach”, 2nd Ed, Elsevier Science & Technology Books,
6. Eduardo, C, 2009, “Heat Transfer in Processing Engineering”, McGraw-Hill, New York.
7. White, F. M., 2010, “Fluid Mechanics”, 6th Ed, McGraw-Hill, New York.

Course Description

Title of Course: Process Modeling & Optimization **Course Code: 14M11CL112**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

This course deals study and analysis of product and process development like creative and assessing the primitive design problem, creating flow sheet, synthesis of reactor-separation trains.

Course outcome

At end of the course students should be able create new ideas, process flow sheets and simulate them using simulation tools to meet the design requirement.

Course Contents

UNIT 1: Introduction **6**

Mathematical models for chemical engineering systems: Fundamentals, introduction to fundamental laws. Examples of mathematical models of chemical engineering systems, constant hold up CSTRs, Gas pressurized CSTR, non-isothermal CSTR. Examples of single component vaporizer, Batch reactor, reactor with mass transfer, ideal binary distillation column, batch distillation with hold up.

UNIT 2: Classification of Mathematical Modeling **7**

Classification of mathematical modeling, static and dynamic models, the complete mathematical model, Boundary conditions, the black box principle. Artificial Neural Networks: Network training, Models of training, Network architecture, Back-propagation algorithm, ANN applications.

UNIT 3: Simulation of Chemical Process **6**

Computer Simulation: Simulation examples of Three CSTRs in series, Gravity Flow tank, Binary distillation column, Non-isothermal CSTR. Models for chemical reaction with diffusion in a tubular reactor, chemical reaction with heat transfer in a packed bed reactor, gas absorption accompanied by chemical reaction.

UNIT 4: Introduction to Optimization **4**

Introduction to process optimization; formulation of various process optimization problems and their classification. Basic concepts of optimization-convex and concave functions, necessary and sufficient conditions for stationary points.

UNIT 5: Optimization Techniques for Single Variable **9**

Optimization of one dimensional function, unconstrained multi variable optimization. Bracketing methods: Exhaustive search method, Bounding phase method Region elimination methods: Interval halving method, Fibonacci search method, Golden section search method. Point-Estimation method: Successive quadratic estimation method. Indirect first order and second order method. Gradient-based methods: Newton-Raphson method, Bisection method, Secant method, Cubic search method. Root-finding using optimization techniques.

UNIT 6: Optimization Techniques for Multivariable **10**

Multivariable Optimization Algorithms: Optimality criteria, Unidirectional search, direct search methods: Evolutionary optimization method, simplex search method, Powell's conjugate direction method. Gradient-based methods: Cauchy's (steepest descent) method, Newton's method. Constrained Optimization Algorithms: Kuhn-Tucker conditions, Transformation methods: Penalty function method, method of multipliers, Sensitivity analysis and Direct search for constraint minimization: Variable elimination method, complex search method. Successive linear and quadratic programming, optimization of staged and discrete processes.

Texts Books:

1. Luyben, William, Process Modelling, Simulation and Control for Chemical Engineers, McGraw Hill, New York, 1990.
2. B.V.Babu, “Process Plant Simulation”, Oxford University.
3. Crowe, C.M., Hamielec, A.E., Hoffman, T.W., Johnson, A.I., Woods, D.R. and Shannon, P.T., 1971, “Chemical Plant Simulation”, Prentice Hall, Inc., Englewood Cliff, New Jersey...
4. Kalyanmoy D. “Optimization for engineering design”, Prentice Hall of India.
5. T. F. Edgar and D. M. Himmelblau, 1989 “Optimization of chemical processes”, McGraw Hill, International editions, chemical engineering series.

Reference:

1. G.S. Beveridge and RS. Schechter, 1970, “Optimization theory and practice” McGraw Hill, New York,
2. Rekllitis, G.V., Ravindran, A, and Ragdell, K.M., 1983 “Engineering Optimization Methods and Applications”, John Wiley, New York.

Course Description

Title of Course: Chemical Reaction Engineering **Course Code: 14M11CL113**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

The main aim of this course to teach the analytical analysis of chemical reactions involving more than one phases and several order; this course also deals reactor design of several type involving ideal and non-ideal behaviour.

Course Outcome

Student should be able to identify the reaction regimes, controlling resistance and design the reactor for the same.

Course Contents

UNIT 1: Kinetics of Gas Absorption with Chemical Reaction 17

Introduction, development of rate equation for gas absorption accompanied by chemical reaction, Application of the film theory to mass transfer accompanied by a single second order reaction, solution by Hikita and Asai approximation, role of gas film resistance, flow chart for regime identification, computer program for regime identification, extension to reaction orders different from unity, role of gas film resistance, computer flow chart for calculation of rate of absorption in the case of A (m,n) order gas liquid reaction, Application of penetration and the surface renewal theories to gas absorption with chemical reaction, penetration theory solution to the instantaneous reaction regime, penetration theory solution to the depletion regime using the Hikita-Asai approximation, surface renewal theory solution for the pseudo first order reaction regime, Mass Transfer accompanied by A(0,0) order reactions, mass transfer accompanied by a (m,0) order reaction, mass transfer accompanied by a (0,n) order reaction.

UNIT 2: Kinetics of Two fluid reactions, both gas-liquid and liquid-liquid 3

Rate equation: for straight mass transfer (absorption) of A, mass transfer of A followed by reaction with B, special cases,

UNIT 3: Models for ideal gas-liquid reactors 3

Introduction, mechanically agitated semi batch gas-liquid contactor design, instantaneous reaction regime, fast reaction regime, slow reaction regime,

UNIT 4: Bubble column reactor design 3

Instantaneous reaction regime, fast reaction regime, slow reaction regime,

UNIT 5: Design of mechanically agitated continuous flow reactor 3

Instantaneous reaction regime, fast reaction regime, slow reaction regime,

Counter current plate column design 3

Instantaneous reaction, fast reaction regime, slow reaction regime,

Packed Column design 3

Instantaneous reaction regime, fast reaction regime,

UNIT 6: Design of gas-liquid and liquid-liquid reactors 3

Factors to consider in selecting a contractor, plug flow gas/ plug flow liquid, plug flow gas/ mixed flow liquid: mass transfer in bubble tank, mixed flow gas/batch uniform liquid :

mass transfer to a stirred batch of liquid, plug flow gas/plug flow liquid: mass transfer plus reaction in a counter current and co-current tower, mixed flow gas/mixed flow liquid: mass transfer plus reaction in an agitated tank contactor, plug flow gas/mixed flow liquid: mass transfer plus reaction in bubble tank contactors, mixed flow gas/batch uniform liquid: absorption plus reaction in a batch agitated tank contactor, to find the time needed for a given operation,

UNIT 7: Modelling of Complex Irreversible gas liquid reactions 3

Irreversible consecutive reactions, irreversible reaction of A(g)with two reacting solvents, consecutive reactions of A(g) and C(l) reacting with single solvent, absorption and reaction of two gases ,

UNIT 8: Theory of mass transfer accompanied by reversible reactions 3

Fast reaction regime, instantaneous reaction, fast-instantaneous reaction regime,

Text Books

1. Levenspiel, O., 1984, “Chemical Reactor Omni book” Oregon Book Store, Corvallis, Oregon, USA.
2. Mann, U., 1999, “Principles of Chemical Reactor Analysis and Design”, Plain Publishing.
3. Doraiswamy, L.K. and Sharma, M.M., 1984, “Heterogeneous Reactions: Analysis, Examples, and Reactor Design Vol. 2: Fluid –Fluid-Solid Reactions”, John Wiley & Sons, New Delhi.
4. Szekely, J., Evans, J.W. and Sohn, H.Y., 1976, “Gas-Solid Reaction”, Academic Press.
5. Danckwerts, P.V., 1970, “Gas-Liquid Reactions”, McGraw-Hill.

Reference Books

1. Fogler, H.S., 2006, “Elements of Chemical Reaction Engineering”, 4th Ed, Prentice Hall.
2. Schmidt, L.D., 2005, “The Engineering of Chemical Reactions”, 2^{nd} Ed., Oxford Press.
3. Froment, G.F. and Bischoff, K.B., 1990, “Chemical Reactor Analysis and Design”, 2^{nd} Ed., John Wiley & Sons, New York.
4. Levenspiel, O., 1999, “Chemical Reaction Engineering”, 3^{rd} Ed., John Wiley & Sons.
5. Westerterp, K.R., Swaaij, W.P.M.V. and Beenackers, A.A.C.M., 1987, “Chemical Reactor Design and Operation”, John Wiley & Sons.
6. Smith, J.M., 1981, “Chemical Engineering Kinetics”, 2^{nd} Ed., McGraw-Hill.
7. Allyn, N.H.C. and Bacon, 1983, “Process Reactor Design”,
8. Carberry, J.J., 1976, “Chemical and Catalytic Reaction Engineering”, McGraw-Hill, New York.
9. Hill, C.G., 1977, “An Introduction to Chemical Engineering Kinetics and Reactor Design”, John Wiley & Sons.
10. Satterfield, C.N., 1980, “Heterogeneous Catalysis in Practice”, McGraw-Hill, New York.

Course Description

Title of Course: Advanced Separation Processes-I **Course Code: 14M11CL114**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

This course deals study and analysis of product and process development like creative and assessing the primitive design problem, creating flow sheet, synthesis of reactor-separation trains.

Course outcome

At end of the course students should be able create new ideas, process flow sheets and simulate them using simulation tools to meet the design requirement.

Course Contents

UNIT 1: PHYSICAL - CHEMICAL PHENOMENA **8**

Diffusivity and mechanism of mass transport, Equation of continuity and equation of change, Diffusion, Dispersion, Diffusivity measurements and prediction in non-electrolytes and electrolytes, Solubility of gases in liquids. Interphase mass transport, in two-phase system and in multi-component systems, Role of diffusion in reaction systems, Mass transfer theories-film, Higbie and surface renewal models and their application.

UNIT 2: MASS TRANSFER WITH AND WITHOUT CHEMICAL REACTION **12**

Fluid-fluid reactions involving diffusional transfer, Physical absorption and absorption accompanied by chemical reaction, Application of mass transfer to reacting systems. Residence time distribution analysis, Mass transfer coefficients, Determination and prediction in dispersed multi-phase contractors under conditions of free forced convection, prediction of mean drop/buddle size of dispersions.

UNIT 3: SELECTION - CLASSIFICATION OF MASS TRANSFER – EQUIPMENT **12**

Choice of techniques, Selection of equipment's for gaseous, particulate and liquidous effluent of various industries such as extractive hydro metallurgy, leaching of ores/leach liquors, Selection of equipment based on Mechanical/non-mechanical, Floor area/Height requirement considerations. Optimum energy/cost considerations.

UNIT 4: DESIGN OF MASS TRANSFER EQUIPMENT **10**

Design and analysis of various mass transfer equipment involving multi-component, multi-phase situations, Design of multi component columns and process strippers, Selection of column diameter and height in stage-wise and differential column contactors.

Text Books

1. Sherwood, T. K., and Wilke, C. R., 1975, "Mass Transfer ", McGraw-Hill Kogukusha Ltd.

2. Hanson, C., 1972, “Recent Advances in Liquid Extraction ", Pergamon Press, London.

Reference Books

1. Bird, R.B., Stewart, W. E. and Lightfort, E. N. , 1960, " Transport Phenomena ", John Wiley and Sons,
2. Welty J.R., Wicks, C. E., and Wilson, R. E., 1976 " Fundamental of Momentum ", Heat and Mass Transfer, John-Wiley and Sons.

Course Description

Title of Course: Chemical Reaction Engineering Lab **Course Code: 14M11CL114**
L-T-P Scheme: 0-0-4 **Course Credits: 2**

Objective: To design the new experiments and perform the experiments

Outcome: Students should get expertise in designing the new experiments.

List of Experiments

1. Determination of Arrhenius parameters.
2. Study of order of a reaction.
3. Study the performance of combination of reactors.
4. Study the performance of PFR
5. Performance Study of Trickle bed reactor
6. Performance Study of fluidized bed reactor
7. RTD Studies in a Mixed Flow Reactor/CSTR.
8. RTD Studies in a Plug Flow Reactor (PFR)
9. RTD Studies in Combined Reactor (PFR Followed by MFR/CSTR)
10. RTD Studies in Mixed Flow Reactors in Series (3 MFR/CSTR)
11. Study the kinetics in packed bed reactor.
12. Study the kinetics in adiabatic batch reactor
13. Study of homogeneous catalysed reaction

Elective I

Course Description

Title of Course: Wastewater Treatment **Course Code: 14M1GCL131**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

This course deals with various types of treatment methods for waste water coming from various sources.

Course outcome

At end of the course students should be able handle various types of wastewater, waste material and their suitable treatment techniques.

Course Content

UNIT 1: Waste water types and pollutants **5**

Definitions, types of waste water, industrial wastewater, municipal wastewater, Wastewater flow rates data calculations. Classification, sources and effect of water pollutant on human being and ecology, eutrophication, dissolved oxygen depletion, natural aeration.

UNIT 2: Sampling, measurements & standards of water quality **6**

Physical impurity: TDS, suspended solids, colour, taste and odour, temperature, Turbidity. Chemical impurity: chlorides, fluoride, metals, alkalinity, DO, nitrogen, phosphorus, hardness, MLSS, ML VSS etc. Biological impurity: BOD, COD, TOC , pathogens etc.

UNIT 3: Physical treatment methods **6**

Screening, mixing and flocculation, gravity separation, settling, grit removal, sedimentation, flotation, aeration etc.

UNIT 4: Chemical treatment methods **2**

Chemical coagulation, chemical precipitation, chemical oxidation, chemical neutralization

UNIT 5: Biological treatment methods **10**

Introduction to microbial metabolism, bacterial growth and energetic, microbial growth kinetics, suspended growth and attached growth process, aerobic and anaerobic system.

UNIT 6: Natural treatment methods **4**

Wetland treatment method, septic tank, infiltration and overland flow.

UNIT 7: Advanced treatment methods **6**

Membrane filtration, adsorption, gas striping, ion exchange, advanced oxidation process etc.

UNIT 8: Design of wastewater treatment plant **3**

Wastewater reclamation and reuse, effluent treatment and disposal.

Text Books:

1. Metcalf et.al. "Waste Water Treatment, Disposal and Reuse", 4^{th} edition, Tata McGraw Hill.

Course Description

Title of Course: Air Pollution Control **Course Code: 14M1GCL132**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

The aim of the course is to provide detailed of air pollution and their control technologies.

Course outcome

At end of the course students should be able to identify various sources of air pollution and recommend suitable pollution minimization control methods.

Course Content

UNIT 1: Sources and effect of air pollution **10**

Sources of air pollution-stationary and mobile, fugitive emissions, secondary pollutants; Effects of air pollution in regional and global scale, air pollution episodes; Emission factors, inventory and predictive equations. Atmospheric meteorology, wind profiles, turbulent diffusion, topographic effects, separated flows, temperature profiles in atmosphere, inversions, plume behaviour.

UNIT 2: Air quality monitoring **10**

Objectives, time and space variability in air quality; air sampling design, analysis and interpretation of air pollution data, guidelines of network design in urban and rural areas. Stack monitoring. Air pollution standards and indices.

UNIT 3: Air pollutants and modeling-Basic concepts **12**

Dispersion of air pollutants and modeling-Basic concepts, inversion layer and mixing height, atmospheric stability classes, theory and application of acoustic sounding (SODAR) technique. Box model, The Gaussian dispersion model-point, area and line sources. Prediction of effective stack height-physics of plume rise, Holland's equation, Brigg's equation, etc. modification of Gaussian dispersion models; indoor air quality models.

UNIT 4: Review of general principles of air pollution control **10**

Design and operation of gravity settling chambers, Design and operation of cyclones. Design and operation of wet dust scrubbers-column scrubbers, jet scrubbers, vortex scrubbers, rotating disc scrubbers, and venture scrubbers. Design and operation of fabric filters. Design and operation of electrostatic precipitators, design and operation of mist separators-baffled mist separators, pressure separators. Control devices for gaseous pollutants with special emphasis on absorption, adsorption and mass transfer consideration, and combustion, control of motor vehicle emissions, indoor air pollution control

Text Books:

1. Air Pollution Control Engineering, Vol. 1, Wang, Lawrence K.; Pereira, Norman C.; Hung, Yung-Tse (Eds.) Human Press, 2004.
2. Air Pollution Control Technology Handbook by Karl B. Schnelle, Charles A. Brown.

Course Description

Title of Course: Cleaner Technology **Course Code: 14M1GCL133**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

This course is designed to explain the concept of cleaner production and minimize pollution.

Course outcome

At end of the course students should be able to identify various types of cleaner production technologies with minimum effects on environment.

Course Content

UNIT 1: Sustainable development **6**

Sustainable development - Indicators of Sustainability - Sustainability Strategies. Barriers to Sustainability - Industrial activity and Environment - Industrialization and sustainable development - Industrial Ecology.

UNIT 2: Cleaner production control **10**

Definition - Importance - Historical evolution - Benefits - Promotion - Barriers - Role of Industry, Government and Institutions - Environmental Management Hierarchy- Source Reduction techniques - Process and equipment optimization, reuse, recovery, recycle, raw material substitution - Internet information & Other CP Resources. Cleaner Production (CP) in Achieving Sustainability - Prevention versus Control of Industrial Pollution - Environmental Policies and Legislations - Regulation to Encourage Pollution Prevention and Cleaner Production

UNIT 3: Cleaner production project development & implementation **8**

Overview of CP Assessment Steps and Skills, Preparing for the Site Visit, Information gathering, and Process Flow Diagram, Material Balance, CP Option Generation Technical and Environmental Feasibility analysis.

UNIT 4: Evaluation **8**

Economic valuation of alternatives - Total Cost Analysis - CP Financing - Establishing a Program - Organizing a Program - Preparing a Program Plan - Measuring Progress Pollution Prevention and Cleaner Production Awareness Plan - Waste audit Environmental Statement.

UNIT 5: Life cycle assessment & environmental management systems **5**

Elements of LCA - Life Cycle Costing - Eco Labelling - Design for the Environment - International Environmental Standards - ISO 14001 - Environmental audit. Industrial applications of CP, LCA, EMS and Environmental Audits.

Text Books:

1. Prasad Modak, C.Visvanathan and Mandar Parasnis "Cleaner Production Audit Environmental System Reviews, No.38, Asian Institute of Technology, Bangkok, 1995.

2. World Bank Group' Pollution Prevention and Abatement Handbook - Towards Cleaner Production "World Bank and UNEP, Washington D.C., 1998.

3. Handbook on Life Cycle Assessment: Operational Guide to the ISO Standards (Eco-Efficiency in Industry and Science) (Hardcover) by Jeroen B. Guinee (Editor) Kluwer Academic Publishers.

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M. Tech II semester							
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1.	14M11CL211	Advanced Separation Processes - II	Core	3	0	0	3
2.	14M11CL212	Advanced Thermodynamics	Core	3	0	0	3
3.	14M11CL213	Environmental Eng. & Waste management	Core	3	0	0	3
4.	14M11CL214	Process Dynamics & Control	Core	3	0	0	3
5.	14M1GCL23x	Elective II	Elective	3	0	0	3
6.	14M19CL291	Seminar / Term Paper	Core	0	0	4	2
			Sub Total				**17**

Course Description

Title of Course: Advanced Separation Processes-II **Course Code: 14M11CL211**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

The aim of the course is to provide basic idea about the modern separation processes.

Course outcome

At end of the course students should be able to apply various types of modern separation processes in process industries, get basic idea about the modern analytical instruments used for identification/concentration measurements of unknown compounds in separation processes.

Course Content

UNIT 1: Introduction: **2**

Separation processes, introduction to membrane science and technology; classification of membranes and membrane based processes; membrane materials: ceramic membrane, polymeric membrane, composite membrane liquid membrane

UNIT 2: Preparation of Membranes: **3**

Preparation of polymeric, ceramic and composite membranes by different methods. Advantage and disadvantages of various methods. Controlling pore size, porosity etc. of membrane during preparation.

UNIT 3: Characterization of Membranes: **3**

Determination of pore size, pore size, thickness, permeability, membrane resistance, ionic character, mechanical, thermal, chemical resistance etc. by various methods and analysis of results by various methods.

UNIT 4: Module and process design: **4**

Introduction, plate and frame model, spiral wound module, tubular module, capillary module, hollow fibre model, comparison of module configurations.

UNIT 5: Transport in Membranes: **10**

Theory and applications of membrane processes: micro filtration, ultra filtration, nano filtration, reverse osmosis, electrodyalysis, dialysis, pervaporation, gas separations, membrane distillation and ion exchange membranes.

UNIT 6: Polarization phenomenon and fouling: **5**

Concentration polarization, turbulence promoters, pressure drop, gel layer model, osmotic pressure model, boundary layer resistance model, concentration polarization in diffusive membrane separations and electro dialysis, membrane fouling, methods to reduce fouling, compaction.

UNIT 7: Other separation Processes: **10**

Pressure swing adsorption, reactive distillation, separation using surfactants, Cloud point extraction, Supercritical fluid extraction etc.

UNIT 8: Advanced analytical instruments: **5**

Theory and working principle of UV-Vis spectrophotometer, HPLC, GC, LCMS, LPSA, DLS, SEM etc.

Text Books

1. J. Seader and Henley, "Separation Processes", Wiley Publishers, 1998.
2. R.W. Baker**,** Membrane Technology and Applications, John Wiley & Sons Ltd, 2004.
3. B.K. Dutta, Principles of Mass Transfer and Separation Processes, Prentice Hall of India Private Limited, 2007.

Course Description

Title of Course: Advanced Thermodynamics **Course Code: 14M11CL212**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

This course deals study and analysis of product and process development like creative and assessing the primitive design problem, creating flow sheet, synthesis of reactor-separation trains.

Course outcome

At end of the course students should be able create new ideas, process flow sheets and simulate them using simulation tools to meet the design requirement.

Course Contents

UNIT 1: Introduction **10**

Basic concepts of thermodynamics, Applications of thermodynamics to flow processes: Compression processes, Duct flow of compressible fluids, Expanders, Thermodynamic analysis of steady-state flow processes: Concept of ideal work, lost work, thermodynamics efficiency, availability

UNIT 2: Solution Thermodynamics **9**

Applications of solution thermodynamics: Liquid phase properties from VLE data, Models for the excess Gibbs energy, Property changes of mixing, Heat effects of mixing processes

UNIT 3: Vapour liquid Equilibria **13**

Chemical reaction equilibria: Multi-reaction equilibria, Fuel cells, Topics in phase equilibria: Gamma/phi formulation of VLE, VLE from cubic equation of state, Equilibrium and stability, Liquid-liquid equilibrium, Vapour-liquid-liquid equilibrium, Solid-liquid equilibrium, Solid-vapour equilibrium, Equilibrium adsorption of gases on solids, Osmotic equilibrium and osmotic pressure

UNIT 4: Molecular Thermodynamics **10**

Introduction to molecular thermodynamics: Molecular theory of fluids, Second virial coefficients from potential functions, Internal energy of ideal gases: microscopic view, Thermodynamic properties and statistical mechanics, Hydrogen bonding and charge transfer complexing, Behaviour of excess properties, Molecular basis for mixture behaviour and VLE by molecular simulation

Text Books

1. Smith, Van Ness and Abbott, 2001, “Introduction to Chemical Engineering Thermodynamics”, McGraw-Hill.
2. Rao, Y. V. C., 2003, “Engineering Thermodynamics through Examples

Course Description

Title of Course: **Environmental Engineering & Waste Management** **Course Code: 14M11CL213**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

The aim of the course is to provide basic idea of environmental engineering and handling techniques of waste material.

Course outcome

At end of the course students should be able to identify various types environmental problem, their solutions and management of various waste materials.

Course Content

UNIT 1: Nexus between energy, environment and development **4**

Human population issues. Environmental ethics and environmental quality

UNIT 2: Types of pollution: **8**

Definition of pollution, Different types of pollution - Air, Water and soil and their local, regional and global aspects.

UNIT 3: Air pollution: **8**

Sources of air pollutants, their sources and behaviour in the atmosphere. Effects of air pollutants on humans, animals, plants and properties. Control approaches.

UNIT 4: Water pollution: **8**

Sources, consequences, control of water pollution

UNIT 5: Soil pollution: **8**

Sources and nature of soil pollution and its harmful effects. Environmental problems associated with noise pollution, oil pollution and radioactive pollution.

UNIT 6: Solid waste management principles: **8**

Sources and generation of solid waste, their nature and chemical composition. Their characterization and classification. Different methods of dispersal and management of solid wastes. Recycling of waste materials.

Text books

1. Mahajan S.P., "Pollution Control in Process Industries", Tata McGraw Hill Publishing Company Limited.
2. Peavy, H.S., Rowe, D.R., Tchobanoglous G., "Environmental Engineering", McGraw Hill 1985.
3. Metcalf et.al. "Waste Water Treatment, Disposal and Reuse", 3rd edition, Tata McGraw Hill.

Reference Books:

1. Davis M.L., Cornwell D.A., "Introduction to Environmental Engineering", 2nd edition McGraw Hill 1981.
2. Rao C.S., “Environmental Pollution Control Engineering", Wiley Eastern.

Course Description

Title of Course: Process Dynamics & Control **Course Code: 14M11CL214**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

This course deals study and analysis of product and process development like creative and assessing the primitive design problem, creating flow sheet, synthesis of reactor-separation trains.

Course outcome

At end of the course students should be able create new ideas, process flow sheets and simulate them using simulation tools to meet the design requirement.

Course Contents

UNIT 1: Preliminaries **8**

Review of basic concepts in process control: Laplace transformation, first order systems, second order systems & their dynamics, Open loop & closed loop control systems, frequency response of closed–loop systems, Bode diagram, stability criterion, Nyquist diagram, Tuning of controller settings.

UNIT 2: Advanced Control Systems **8**

Introduction to multiple loop control systems, Cascade control, feed forward control, Inferential control, Adaptive & ratio control with chemical engineering applications.

UNIT 3: Multivariable Processes **12**

Model based control; Multivariable control strategies; Model predictive control; Analysis of Dynamic Matrix Control (DMC) & Generalized Predictive Control (GPC) schemes; Controller tuning & robustness issues. Extensions to Constrained & Multivariable cases.

UNIT 4: Applications: **7**

Examples for control of heat exchangers, distillation column & reactors.

UNIT 5: Use of Computers **7**

Introduction to microprocessors & computer control of chemical processes.

Text Books

1. George Stephanopolous, “Chemical Process Control”, Prentice–Hall of India Pvt-Ltd., New Delhi, 1990.
2. Luyben and Luyben, 1996,”Essentials of Process Control”, McGraw-Hill.

Reference Books

1. L.Ljung, 1987, “System Identification–Theory for the User”, Prentice Hall.
2. E.Camacho and C.Bordons, 1995. “Model Predictive Control in the Process Industry”.
3. B.G.Liptak, “Instrument Engineer’s Handbook”, Volume 1&2, CRC Press.

Elective II

Course Description

Title of Course: Process Plant Simulation **Course Code: 14M1GCL231**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

Computer aided analysis of chemical process systems; classification and development of mathematical models to various chemical engineering systems; decomposition of networks; tearing algorithms; numerical methods for convergence promotion and solving chemical engineering problems; traditional & non-traditional optimization techniques; specific purpose simulation; dynamic process plant simulation; case study problems using professional software packages

Course Outcome

After completing this course, student should too able to simulate any process flow sheet for given task.

Course Content

UNIT 1: Introduction 2

Introduction to Process Synthesis, Analysis, Design and Simulation

UNIT 2: Mathematical Modelling 2

Classification of Mathematical Modelling, Similarity Criteria, Variables, Parameters, etc.

UNIT 3: Chemical Systems Modelling 8

Modelling of various Chemical systems covering heat, mass, and momentum transfer, and reactions.

UNIT 4: Modular Approaches to Process Simulation 3

Sequential and Simultaneous Modular Approaches to be used in process plant simulation

UNIT 5: Equation Solving Approach 5

Partitioning, Decomposition, Disjointing, PTM, SWS-, Steward-, and Rudd-Algorithms, Sparcity, Direct Methods, Pivoting, Iterative methods, BTF, BBTF, Block Back Substitution, BTS, etc.

UNIT 6: Decomposition of Networks 7

Tearing Algorithms in decomposition of networks, digraph, MCN, signal flow graph, B&M Algorithm, BTA, K&S Algorithm, M&H-1 & -2 Algorithms, and related problems.

UNIT 7: Convergence Promotion 1

Convergence Promotion methods such as Newton's method, Direct substitution, Wegstein's method, Dominant Eigen value method, Quasi-Newton methods, Acceleration criterion, etc.

UNIT 8: Physical and Thermodynamic Properties 1

Sources and data banks of physical & thermodynamic properties, Modularity & Routing.

UNIT 9: Optimization Techniques 6

Importance & applications, limitations, types, methods, direct search routines, Lagrangian multiplier method, Gradient methods (Method of steepest descent & sequential simplex method); Non-traditional optimization techniques such as simulated annealing, genetic algorithms, differential evolution, etc.

UNIT 10: Specific Purpose Simulation 3

Case studies such as Casale converter for ammonia production, etc. on specific purpose simulation, and use of professional simulation packages.

UNIT 11: Dynamic Simulation 2

Case studies such as dynamic distillation modelling and simulation, etc. on Dynamic Simulation, and use of professional simulation packages.

Text Book:

1. Babu, B. V., 2004, "Process Plant Simulation", Oxford University Press, India.

Reference Books:

1. Onwubolu, G. C. and Babu, B. V., 2004, "New Optimization Techniques in Engineering; Springer-Verlag, Germany.
2. Luyben, W.L., 1990, "Process Modelling, Simulation and Control for Chemical Engineers", 2nd Ed., McGraw-Hill, New York.
3. Franks, R. G. E., 1972, "Modelling and Simulation in Chemical Engineering", John Wiley & Sons, New York.
4. Boyadjiev, C., 2010, "Theoretical Chemical Engineering: Modelling and Simulation", Springer Verlag, London.

Course Description

Title of Course: Colloidal & Interfacial Engineering **Course Code: 14M1GCL232**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

In this course students will study understand the phenomena occur in the colloids and the importance of colloids and role of interfacial engineering and study near the interface processes. Role of colloids in industry is also covered like drug delivery, paints and textile etc.

Course Outcome

Students should be able to identify the colloidal and interfacial phenomena taking place in chemical processes and use them for further development.

Course Contents

UNIT 1: Fundamental of Interfacial Tension 5

Introduction to Interfacial Phenomena , Interfacial Tension: qualitative Considerations ,Interfacial Tension: Thermodynamic Approach , Vapour Pressure of a Drop , Interfacial Tension: Mechanical Approach, Locating the Dividing Surface , Density and Concentration Profiles , Equilibrium Shapes of Fluid Interfaces, Dimensions of a Sessile Drop , Shape of a Soap Film between Parallel Rings, Methods of Measuring Interfacial Tension , Capillary Rise in Air-Water and Oil-Water ,Surface Tension of Binary Mixtures , Surface Tension of Ideal Binary , Surface Tension of Regular Solutions, Surfactants, Solid-Fluid Interfaces

UNIT 2: Fundamentals of Wetting, Contact Angle, and Adsorption 5

Introduction ,Young's Equation , Work of Adhesion and Work of Cohesion, Phenomenological Theories of Equilibrium Contact Angles ,Acid-Base Interaction , Contact Angle , Hysteresis, Impurities on the Surface, Effect of Adsorption ,Surface Roughness ,Adsorption, Langmuir Adsorption Isotherm , The Brunauer-Emmett-Teller Isotherm , Density Profiles in Liquid Films on Solids, Characterizing Solid Surfaces

UNIT 3: Colloidal Dispersion 4

Introduction ,Attractive ,Electrical Interaction, Colloids of All Shapes and ,Combined Attractive and Electrical Interaction: DLVO ,Effect of Polymer Molecules on the Stability of Colloidal Dispersions , Kinetics of Coagulation

UNIT 4: Surfactants 6

Introduction ,Micelle Formation, Estimation of Micelle Aggregation Number and CMC, CMC of ,Variation of CMC for Pure Surfactants and Surfactant Mixtures , Other Phases Involving Surfactants, Cylindrical Micelles, Formation of Complexes between Surfactants and Polymers ,Surface Films of Insoluble Substrates, Solubilisation and Micro emulsions , Phase Behaviour and Interfacial Tension for Oil-Water-Surfactant Systems, Effect of Composition Changes, Effect of Composition and Temperature on Optimal Salinity, Thermodynamics of Micro emulsions, Applications of Surfactants: ,Applications of Surfactants: Detergency, Chemical Reactions in Micellar Solutions and Micro emulsions

UNIT 5: Interfaces in Motion: Stability and Wave Motion 5

Background ,Linear Analysis of Interfacial Stability , Differential Equations, Boundary Conditions, Stability Condition and Wave Motion for Superposed ,Characteristics of Wave Motion for Free Interfaces ,Damping of Capillary Wave Motion by Insoluble Surfactants, Characteristics of Wave Motion for Inextensible Interfaces, Instability of Fluid Cylinders or Jets, Oscillating Jet , Surface Tension of Oscillating Jets , Stability and Wave Motion of Thin Liquid Films: Foams and Wet ability, Stability of a Liquid Film, Energy and Force Methods for Thermodynamic Stability of Interfaces , Energy Method for Stability of Superposed Fluids , charged interfaces

UNIT 6: Interfacial Stability for Fluids in Motion: Kelvin-Helmholtz 5

Instability , Kelvin-Helmholtz Instability for Air-Water System , Peak Heat Flux ,Waves on a Falling Liquid Film, Wave Motion on Falling Water Film

UNIT 7: Transport Effects on Interfacial Phenomena 4

Interfacial Tension Variation, Interfacial Species Mass Balance and Energy Balance , Interfacial Instability for a Liquid Heated from Below or Cooled from Above ,Conditions for Development of Marangoni Instability, Interfacial Instability during Mass Transfer , Other Phenomena Influenced by Marangoni Flow, Non equilibrium Interfacial Tensions , Effect of Surfactant Transport on Wave Motion ,Stability of Moving Interfaces with Phase Transformation, Characteristics of Interfacial Instability during Solidification, Stability of Moving Interfaces with Chemical Reaction , Intermediate Phase Formation , Transport-Related Spontaneous Emulsification , Interfacial Mass Transfer Resistance, Other Interfacial Phenomena Involving Dispersed Phase Formation

UNIT 8: Dynamic Interfaces 4

Introduction , Surfaces , Basic Equations of Fluid Mechanics, Flow Past a Droplet , Asymptotic Analysis , Dip Coating, Spherical Drop Revisited , Surface Rheology, Drainage of Thin Liquid Films , Dynamic Contact Lines , Slip ,Thin and Ultrathin Films .

UNIT 9: Colloids in Drug Delivery 4

Surfactants and block copolymers in drug delivery, Application of colloids in drug delivery, Micelles: multifunctional nano-carrier for colloidal drug delivery, colloids in aerosol drug delivery systems, colloidal carrier for drug delivery in dental tissue engineering, classification and application of colloidal drug delivery system

Text Books

1. Miller, C. A. and Neogi, P., 2008, “Interfacial Phenomena Equilibrium and Dynamic Effects”, 2nd Ed., CRC, New York.
2. Saw, D. J., 2000, “Introduction to Colloid and Surface Chemistry”, 4th Ed, Butterworth Heinemann, New York.
3. Fanun, M., 2010, “Colloids in Drug Delivery”, CRC Press, Boca Raton.

4. Berg, J. C., 2009, “An Introduction to Interfaces and Colloids: The Bridge to Nanoscience”, World Scientific.
5. Binks , B. P., 2006, “Colloidal Particles at liquid interface”, Cambridge Uni. Press, USA

Course Description

Title of Course: Advances in Process Control **Course Code: 14M1GCL233**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

This course deals study and analysis of product and process development like creative and assessing the primitive design problem, creating flow sheet, synthesis of reactor-separation trains.

Course outcome

At end of the course students should be able create new ideas, process flow sheets and simulate them using simulation tools to meet the design requirement.

Course Contents

UNIT 1: Introduction to process control **6**

Dynamic and steady state processes, development of block diagram and its reduction, PID control algorithm. routh stability criteria, bode plots, root locus

UNIT 2: Introduction to Advanced Controllers **6**

Feed forward, ratio controller, cascade, controller, adaptive controller, inferential controller.

UNIT 3: SISO and MIMO **8**

Review of Single Input Single Output (SISO) Control; Model Based Control; Multivariable control strategies Internal Model Control Preliminaries & Model Predictive Control; Model forms for Model Predictive Control.

UNIT 4: Automatic controllers **8**

Analogue & digital signals, process actuators & control equipment; Electronic, Controllers, Operational amplifier, Electronic controller input & output, PID & on- off control models, Microprocessors, General architecture, Algorithms, Application in Chemical Process Control.

UNIT 5: Process control using digital computers **8**

Characteristics & performance of control computer , signals –types, Signal transmission , Analog feedback control systems; The direct digital control concept, Advantages of DDC , Computer process interface for data acquisition & control , Computer control loops.

UNIT 6: ANN and Fuzzy Logic **6**

Introduction to computer control using artificial neural network (ANN) & fuzzy logic applied to chemical processes. Examples of advanced control applied to a small unit in a process plant.

Text Book

1. George Stephanopolous, 1990, “Chemical Process Control”, Prentice –Hall of India Pvt-Ltd., New Delhi.

2. Peter Harriott, 1977, “Process control “, Tata McGraw-Hill Publishing Co. Ltd., New Delhi.

Reference Books

1. G.K.McMillan and D.M.Consdine, 1999, “Process/ Industrial Instruments and controls Handbook “, McGraw-Hill.

2. B.G.Liptak, “Instrument Engineer’s Handbook”-Volume 1&2, CRC Press.

3. Emanule and S. Savas, 1965, “Computer Control of Industrial Processes”, McGraw-Hill London.

Course Description

Title of Course: Applied Optimization & Operations Research **Course Code: 14M1GCL234**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

This course deals study and analysis of product and process development like creative and assessing the primitive design problem, creating flow sheet, synthesis of reactor-separation trains.

Course outcome

At end of the course students should be able create new ideas, process flow sheets and simulate them using simulation tools to meet the design requirement.

Course Contents

UNIT 1: Optimization techniques **8**

Function, Analysis and numerical methods for single variable and multivariable system, constrained optimization Problems

UNIT 2: Application of optimization **7**

Heat transfer and energy conservation, Separation techniques, Fluid flow systems, Chemical Reactor design

UNIT 3: Mathematical programming **9**

Introduction, Linear Programming, Solution by simplex method, Duality, Sensitivity analysis, Dual simplex method, Integer Programming, Branch and bound method, Integer Programming, Branch and bound method

UNIT 4: Dynamic programming **6**

Elements of DP models, Bellman's optimality criteria, Recursion formula, solution of multistage decision problem by DP method

UNIT 5: Pert, Cpm **7**

Network representation of projects, critical path calculation, construction of the time chart and resource levelling, Probability and cost consideration in project scheduling, Project control

UNIT 6: Elements of queuing theory **6**

Basic elements of the Quening model, M/M/I and M/M/C Quenes

UNIT 7: Elements of reliability theory **6**

General failure distribution, for components, Exponential failure distributions, General model, Maintained and non-maintained systems.

Text Book

1. Edgar, T.F. and D.M. Himmelblau, 1989, “Optimization of Chemical Processes ", McGraw Hill Book Co., New York.

2. Hamdej A. Taha, 1982, “Operations Research, an introduction ", Macmillan Publishing Co., Third Edition.

Reference Book

1. Narayan Bhatt, 1972, “Elements of Applied Stochastic Processes ", John Wiley and Sons.

2 year M. Tech Course Curricula for Chemical Engineering							
M. Tech III semester							
S. N.	**Course Code**	**Course Title**	**Type**	**L**	**T**	**P**	**Credits**
1.	14M1GCL33x	Elective-III	Elective	3	0	0	3
2.	14M1GCL33x	Elective-IV	Elective	3	0	0	3
3.	14M19CL391	Project Seminar	Core	0	0	4	2
4.	14M19CL392	Thesis	Core	0	0	24	12
			Sub Total				**20**

<u>Elective III</u>

Course Description

Title of Course: Petroleum Refinery Operations **Course Code: 14M1GCL331**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

This course deals study and analysis of product and process development like creative and assessing the primitive design problem, creating flow sheet, synthesis of reactor-separation trains.

Course outcome

At end of the course students should be able create new ideas, process flow sheets and simulate them using simulation tools to meet the design requirement.

Course Contents

UNIT 1: Petroleum Refining **3**

Pre-treatment and Distillation, Stripping, Rerunning, Stabilization and Light End Removal, Super fractionation, Azeotropic Distillation and Extractive Distillation

UNIT 2: Thermal Cracking **3**

Introduction, Thermal Cracking, Visbreaking, Coking, Delayed Coking, Fluid Coking and Flexi coking

UNIT 3: Catalytic Cracking **5**

Introduction, Fixed Bed Processes, Moving Bed processes, Fluid Bed processes, Reaction chemistry of FCC, Mechanism and Kinetics, Process Variables: Feedstock Quality, Feedstock Preheating, Feedstock Pressure, Feedstock Conversion, Reactor Temperature, Recycle Rate, Space Velocity, Catalyst Activity, Catalyst Oil Ratio, Regenerator Temperature, and Regenerator Air Rate. Catalysts for Cracking

UNIT 4: Hydro treating **5**

Introduction, Hydrodesulphurization: Process configuration, Reaction chemistry and Kinetics, Down flow Fixed Bed Reactor, Up flow expanded Bed Reactor, De-metallization Reactor (Guard Bed Reactor), Catalysts. Distillate Hydro-sulfurization, Residuum Hydro-desulfurization, Ultra low sulphur Diesel.

UNIT 5: Hydrocracking **5**

Introduction, Processes and Process Design: Reaction chemistry and Kinetics, CANMET, Gulf HDS, H-G Hydrocracking, H-Oil. IFP Hydrocracking, Isocracking, LC fining, MAK, HDC, Microcat RC, Mild Hydrocracking, MRH, RCD, Unibon (BOC), Residfining, Residue

Hydro conversion, Unicrackking, Veba, Combi-Cracking

UNIT 6: Next Generation Processes **8**

Introduction, Thermal (Carbon Rejection) Processes: Asphalt Coking Technology Process, Comprehensive Heavy Ends reforming Refinery Processes, Deep Thermal Conversion Process, ET –II Process, Eureka Process, Fluid Thermal Cracking Process, High Conversion Soaker Cracking Process, Catalytic Cracking Processes: Asphalt Residue Treating Process, Heavy Oil Treating Process, Reduced Crude Oil Conversion Process, Residual Fluid Catalytic Cracking Process, Shell FCC Process, S&W Fluid Catalytic Cracking Process, Hydrogen Addition Processes, Asphaltenic Bottoms Cracking Process, Hydrovisbreaking (HYCAR) Process, Solvent Processes: Deasphalting Process, Deep Solvent Deasphalting Process, Demax Process

UNIT 7: Product Improvement **3**

Desulfurization and Heteroatom Removal: Hydrotreating, Hydrogen Sulphide Removal Reforming: Thermal Reforming, Catalytic reforming, Dehydrogenation, Catalysts, Reformulated Gasoline and other oxygenates like MTBE and others.

UNIT 8: Isomerisation, Alkylation and Polymerization **2**

Process Types, Chemistry, Commercial Processes, Catalysts

UNIT 9: Hydrogen Production **5**

Introduction, Feed stocks, Process Chemistry, Commercial Processes: Heavy Residue Gasification and Combined Cycle Power Generation, Hybrid Gasification Process, Hydrocarbon Gasification, Hypro Process, Shell Gasification (Partial Oxidation) Process, Steam Methane Reforming, Steam Naphtha Reforming, Synthesis Gas Generation, Texaco Gasification (Partial Oxidation) Process. Catalysts, Hydrogen Purification

UNIT 10: Alternative sources of Petroleum based applications **3**

Hydrogen production and Fuel cells, Gas to Liquid Fuels, First & Second Generation Bio fuels

Text Books:

1. B.K.B. Rao, “Modern Petroleum Refining Processes”, Oxford & IBH Publishing Pvt. Ltd.

2. C.S. Hsu and P.R. Robinson, “Practical Advances in Petroleum Processing”, Springer Publications.

Reference Books:

1. W.L. Nelson, “Petroleum Refinery Engineering”, McGraw-Hill International

2. G.N. Sarkar, “Advanced Petroleum Refining”, Khanna Publishers

Course Description

Title of Course: Polymer Science & Engineering **Course Code: 14M1GCL333**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

In this course, the basic concepts of polymerization techniques, kinetics, several properties of polymers with structures and upcoming applications will be dealt with. The present course aims to help the students in selection of the polymerization technique, required by the industries. This course also gives an exposure to the students in the field of advancement of the course through projects related to recent research topics.

Course Outcome

On completion of this course, student will have sufficient knowledge and confidence to perform research in above mentioned field and design the polymer to meet future demands.

Course Contents

UNIT 1: Introduction to Polymer Science 2

Classification of polymers, polymer structure, molecular weight, chemical structure and thermal transition

Synthesis of Polymers 10

UNIT 2: Step growth polymerization : condensation polymerization , non-condensation polymerization , kinetics of step growth polymerization, Chain growth polymerization: free radical polymerization & its kinetics, Anionic polymerization and its kinetics, Cationic polymerization and its kinetics, Copolymerization & its kinetics, Coordination polymerization and its kinetics.

UNIT 3: Polymerization Techniques 2

Bulk polymerization, solution polymerization, suspension polymerization & Emulsion polymerization.

UNIT 4: Solution properties and molecular weight determination 7

Solution properties, membrane osmometry, vapour pressure osmometry, end group analysis, light scattering method, intrinsic-viscosity Measurement, sedimentation transport, gel-permeation chromatography.

UNIT 5: Solid-state properties of polymers

Amorphous state, chain entanglements & reptation, glass transition, crystalline state, crystalline melting temperature, crystallization kinetics, techniques to determine crystallinity 3

UNIT 6: Thermal transition & properties 2

Fundamental thermodynamic relationship, thermal transition in polymeric material, determination of Tg by dilatometry and calorimetry.

UNIT 7: Mechanical properties 2

Test to determine mechanical performance in polymers, Static test: tensile, shear, Transient test: creep test, stress relaxation, impact & cyclic test

UNIT 8: Viscoelasticity 2

Introduction to viscoelasticity, Dynamic-mechanical analysis, Mechanical models of viscoelastic behaviour

UNIT 9: Polymer Rheology 3

Introduction to Polymer Rheology, Analysis of Simple Flows, Rheometry.

Polymer degradation, stability and environmental issues 1

Thermal degradation oxidative & UV-stability, management of plastics in environment.

Polymer additives 2

Fillers, plasticizers, stabilizers, colorants, flame retardant

Commercial polymers 2

Thermoplastics, Thermosetting polymers, Elastomers, Vulcanization

Engineering and specialty polymers 0

Self-study

UNIT 10: Polymer processing 3

Extrusion, moulding, spinning calendaring, coating.

Text Book:

1. Fried, J. R., 1995, “Polymer Science and Technology”, Prentice Hall of India, New Delhi.

Reference Books:

1. Bill Meyer, F. W. Jr, 1994, “Textbook of Polymer Science”, 3rd Ed., John Wiley & Sons, New York.
2. Rudin, A., 1999, “Polymer Science and Engineering”, 2nd Ed., Academic Press, USA.
3. Gowarikar, V.R., 1986, “Polymer Science”, 1st Ed, New Age International (P), Ltd.

Course Description

Title of Course: Combustion Processes **Course Code: 14M1GCL334**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

The purpose of this course is to provide theoretical knowledge about combustion process, flames and various combustion applications in process industries.

Course outcome

After the completion of this course, student will be handle different types of combustion processes optimally and apply them in process industries.

Course Content

UNIT 1: Combustion Fundamentals **10**

Introduction, Energy Sources, Fuels, Fuel cells, Combustion Stoichiometry and Thermochemical Calculations, Chemical Kinetics and Equilibrium: Kinetic theory of gases, Chemical kinetics, Reaction kinetics, Equilibrium composition and temperature, Conservation, energy and equilibrium equations, Transport Phenomena, and Modelling of Real gases, Transport properties of multi-component mixtures, Combustion Generated Air Pollution, Pollutants Formation and Oxidation Kinetics, Pollutant Emissions Reduction Techniques.

UNIT 2: Laminar Premixed Flames **10**

Introduction, Flammability limits, Laminar flame stabilization, Flame temperature, Burning velocity of a premixed flame, Stationary methods, Propagation methods, Ignition. Theory and Kinetics of Laminar Premixed Flames, Simple Fuels-N2-O2 Flames, Hydrogen-oxygen-nitrogen flames,Hydrogen-H2O-CO-O2-N2 flames, Methane-oxygen-nitrogen flames, Methanol-air flames, Methanol-water-air flames, Propane-air flames, Ethane-air flames, Natural gas-air flames, Generalization of Flame Characteristics, Effect of Fuel Type and Additives on Emissions and Flame Characteristics.

UNIT 3: Turbulent Premixed and Diffusion Flames **7**

Characteristics of Diffusion Flames, Turbulent Burning, Turbulence Models Interaction Between Turbulence and Chemical Kinetics, Flame Stabilization, Turbulent Premixed Flames.

UNIT 4: Characteristics of Turbulent Confined Diffusion Flames **8**

Mixing and Flow Fields of Jets, Swirling Flows in Combustion Systems, Flow and Mixing in Cold Models, Characteristics of Confined Flames, Emission and Combustion Modelling in Flames.

UNIT 5: Combustion, Heat Transfer, Emission In Boilers and Furnaces **7**

Steam Boilers, Tangentially-Fired Furnaces (TFFs) , Fluidized-Bed Furnaces (FBFs)

Text Book:

1. Fawzy El-Mahallawy, Saad El-Din Habik Fundamental and technology of combustion: 2002, Elsevier.

Course Description

Title of Course: Environmental Management **Course Code: 14M1GCL335**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

The aim of the course is to provide basic idea about the environmental pollution, their possible treatment methods and Conventional and non-conventional energy resources.

Course outcome

At end of the course students should be able to identify various types' environmental pollution, their treatment methods and suitable recommend energy sources for minimization of pollution.

Course Content

UNIT 1: Introduction to different types of pollution **8**

Air, Water and soil and their local, regional and global aspects. Sampling and analysis techniques. Human population issues. Environmental ethics and environmental quality.

UNIT 2: Air pollution **8**

Sources of air pollutants, their sources and behaviour in the atmosphere. Effects of air pollutants on humans, animals, plants and properties. Control approaches.

UNIT 3: Water pollution **8**

Sources, consequences, control of water pollution. Sources and nature of soil pollution and its harmful effects. Environmental problems associated with noise pollution, oil pollution and radioactive pollution.

UNIT 4: Solid waste **10**

Sources and generation of solid waste, their nature and chemical composition. Their characterization and classification. Different methods of dispersal and management of solid wastes. Recycling of waste materials. Impact assessment. National and International regulations. ISO series.

UNIT 5: Conventional and non-conventional energy resources **8**

Bio gas, Solar Power, wind power, life cycle analysis. Environmental audit. Sustainable development. Case studies.

Text Books

1. Deneves, "Air Pollution Control Engineering", Mc .Graw hill, 1999.
2. Jr. W.C. Blackman, "Basic Hazardous Waste Management", CRC Press.
3. K.L. Mulholland, J.A. Dye, "Pollution Prevention: Methodology, Technologies and Practices", Wiley.

Reference Book

1. T.K. Das, “Toward Zero Discharge: Innovative Methodology and Techniques for Process pollution”, Wiley-VCH, 2005.

Elective IV

Course Description

Title of Course: Fluidization Engineering **Course Code: 14M1GCL332**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

This course deals study and analysis of product and process development like creative and assessing the primitive design problem, creating flow sheet, synthesis of reactor-separation trains.

Course outcome

At end of the course students should be able create new ideas, process flow sheets and simulate them using simulation tools to meet the design requirement.

Course Contents

UNIT 1: Introduction **3**

Phenomenon of fluidization, Behaviour of a Fluidized Bed, Comparison with other contacting methods, Advantages and Disadvantages of Fluidized Beds for Industrial Operations, Fluidization Quality, Selection of a Contacting Mode for a given Application.

UNIT 2: Industrial Applications of Fluidized Beds **4**

Coal Gasification, Gasoline from other Petroleum Fractions, Gasoline from Natural and Synthesis Gases, Synthesis Reactions, Metallurgical and Other Processes, Physical Operations, Cracking of Hydrocarbons, Combustion and Incineration, Carbonization and Gasification and Reactions Involving solids, Bio –fluidization

UNIT 3: Fluidization and Mapping of Regimes **7**

Characterization of Fixed Beds of Particles, Fluidization without Carryover of Particles: Minimum Fluidizing Velocity, Pressure Drop-verses-Velocity Diagram, Effect of Pressure and Temp. on Fluidized Behaviour, Sintering and Agglomeration of Particles at High Temperature. Type of Gas Fluidization with and without Carryover, Turbulent and Churning Fluidization, Pneumatic Transport of Solids, Fast Fluidization, Voidage Diagrams for all Solid Carryover, Regimes, The Mapping of Fluidization Regimes

UNIT 4: Bubbles in Dense Beds **6**

Single Rising Bubbles: Rise Rate of Bubbles, Evaluation of Models for Gas Flow at Bubbles, The Wake Region and the Movement of Solids at Bubbles, Solids within Bubbles. Coalescence and Splitting Bubbles: Interaction of Two Adjacent Bubbles, Coalescence, Bubble Size and Bubble Frequency, Splitting of Bubbles and Maximum Bubble Size, Bubble Formation above a Distributor, Slug Flow

UNIT 5: Bubbling Fluidized Beds **6**

Emulsion Movement for small and Fine Particles, Emulsion Movement for Large Particles, Emulsion gas flow and Voidage, Effect of Pressure on Bed Properties, Estimation of Bed Properties: Gas Flow in the emulsion phase, Bubble Gas Flow, Bubble Size and Bubble growth, Bubble Rise Velocity, Beds with Internals, Physical Models: Scale up and scale down

UNIT 6: Flow Models for Bubbling Beds **3**

General Interrelationship among Bed Properties, Simple Two-phase Model, K-L Model with its Davidson Bubbles and Wakes

UNIT 7: High Velocity Fluidization **4**

Turbulent Fluidized Beds, Experimental Findings, Fast Fluidization, The Freeboard Entrainment Model Applied to Fast Fluidization, Design Considerations, Pressure Drop in Turbulent and Fast Fluidization

UNIT 8: Circulation Systems **6**

Circuits for the Circulation of Solids, Finding Required Circulation Rates, Flow of Gas-Solid Mixtures in down comers: Downward discharge from a Vertical Pipe, Moving Bed Down flow, Fluidized Down flow, Fluidized Down flow in Tall Down comers. Flow in Pneumatic Transport Lines: Vertical Up flow of Solids, Horizontal Flow, Safe Gas Velocity for Pneumatic Transport, Pressure Drop in Pneumatic Transport, Pressure drop in Bends, Practical Considerations

UNIT 9: Design of Fluidized bed Reactors **3**

Design of catalytic and non-catalytic fluidized bed reactors.

Text Book

1. Kunii, D and Levenspiel, O., “Fluidization Engineering”, 2nd Edition, Butterworth-Heinemann, Elsevier.

Reference Book

1. Wen-Ching Yen, 1999, “Fluidization, Solid Handling and Processing: Industrial Application”, Noyes publication.

2. M. Kwauk, 1994, “Fast Fluidization”, Vol 20, Advances in chemical Engineering, Academic Press.

3. L. G. Gibilaro, 2011, “Fluidization Dynamics”, Butterworth-Heinemann

Course Description

Title of Course: Multiphase Contactors **Course Code: 14M1GCL336**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

In the course, detailed analysis of multiphase contactors like packed bed, fluidized bed, trickle bed etc. is covered. This course also deals the design modelling of multiphase reactors; separator and their dynamics will be studied.

Course Outcome

Students will get hands on various multiphase contactors design and modelling.

Course Contents

UNIT 1: Mathematical Models for Gas-Liquid-Solid Reactors 3

Models based on effectiveness of contact, with no external mass transfer resistances (models for trickle-bed reactors) , Reactor performance based on residence-time distribution , Model when reactant present in both liquid and vapour phases ,Models for non-isothermal trickle-bed reactors, Models which include external mass-transfer effects, Models for three-phase slurry reactors, Models for the packed-bubble-column gas- liquid reactors.

UNIT 2: Fixed Bed Catalytic Reactors 3

Systems and mathematical models, general concepts, outline of the procedure for model building, basic principles of mathematical modelling for industrial fixed bed reactors.

UNIT 3: Practical Relevance of Bifurcation, Instability And Chao in Catalytic Reactors 3

Sources of multiplicity: isothermal multiplicity, concentration multiplicity, thermal multiplicity, multiplicity due to reactor configuration, quantitative discussion of the multiplicity phenomenon, bifurcation and stability, steady state analysis and dynamic analysis.

UNIT 4: Optimization of The Performance of Industrial Fixed Bed Catalytic Reactors 6

Objective functions, optimal and suboptimal temperature control policies, optimization of reversible reactions, Pontryagin maximum principle and simple optimality criterion for exothermic reversible reaction, modelling, simulation and optimization of industrial fixed bed catalytic reactors, case studies: mathematical modelling of high/low temperature water-gas shift converter, modeling of ammonia converters, precise modeling of industrial steam reformers and methanators.

UNIT 5: Design of Multiphase Reaction Processes 4

Multiphase Reaction Processes and Chemical Engineering, Reason for Adopting Multiphase

Reactors.

UNIT 6: Model Description of Multiphase Processes 3

Governing Equations for State Variables of Each Phase, Dispersed Phase Modelling and Population Balance, Relationship between the Multi-stage Cell model and the Continuous model.

UNIT 7: Mechanical and Morphological Variety of Each Phase and Contacting Mode Parameters 3

Relations between Parameters, Behaviour of an Isolated Particle (Solid Particle, Bubble and Droplet), Behaviour of Multi-particle Systems, Behaviour of Solid Dispersed Systems, Mass Transfer Volumetric Coefficient and Gas Exchange Coefficient, eddy diffusivity, The importance of the State of the Interface.

UNIT 8: Concepts of Multiphase Reaction Processes 3

Alternatives to the State of the Interface, Systems with Flat Interfaces, Systems with One or More Phases Dispersed, Systems with Stabilized Dispersions, Systems with Forced Mechanical Dispersion, Contacting Systems with a Porous Material.

UNIT 9: Options for Reacting Systems and Reactor Structures 5

Batch/Semi-batch (Semi-continuous) / Continuous, Entrained Flow/Separate Flow, Complete Mixing / Incomplete Mixing / Plug Flow, Co-current/ Counter current /Cross Current, Uniform Reactions/Zone Reactions/Surface Reactions, Micro Mixing/Macro Mixing, and Molecular Diffusion/Eddy Diffusion, Statics/ Dynamics/ Stability.

UNIT 10: Development and Scale-Up of Multiphase Reactors 3

The Nature of Development and Scale-up Issues, Methodology of Development and Scale-up.

UNIT 11: Dynamics of the Gas-Liquid Suspended-solid Column 6

Introduction, Hydrodynamics, Gas, liquid , and solid holdups, Axial dispersion in the gas, liquid, and solid phases, Gas-liquid interface mass transfer, Liquid- sol id mass transfer, Wall mass transfer in the slurry column, Heat transfer.

Text Books

1. Elnashie, S.S.E.H. and Elshishini, S.S., 1993, “Modelling, Simulation, and Optimization of Industrial Catalytic Reactors”, Gordon and Breach Science Publishers, Amsterdam
2. Ranade, V.V., Chaudhary, R. and Gunjal, P.R., 2011, “Trickle Bed Reactors: Reactor Engineering & Applications”, Elsevier.
3. Shah, Y.T., 1979, “Gas –Liquid-Solid Reactor Design”, McGraw-Hill, New York.
4. Tominaga, H. and Tamaki, M., 1997, “Chemical Reaction and Reactor Design”, John Wiley & Sons, New York.
5.

Course Description

Title of Course: Catalysis & Surface Chemistry **Course Code: 14M1GCL337**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

This course deals with surface chemistry of catalyst, methods for catalyst preparation, reaction mechanism and their characterization. Case studies of preparation of several important industrial catalysts.

Course Outcome

Student will learn latest techniques available for catalyst preparation, characterization and new advancements.

Course Contents

UNIT 1: History of Catalysis 3

Introduction, Industrial Catalysis, Catalytic Processes In The Oil Refinery, Total Isomerization Process of Paraffins, Isotacttic Polypropylene, Catalysts For Automotive Pollution Control.

UNIT 2: Chemical Kinetics of Catalysed Reactions 3

Rate Expression (Single Site Model), Rate Determining Step, Adsorption Isotherms, Rate Expression (Other Models), Initial Rate Expressions, Temperature Dependency, Sabatier Principles – Volcano Plot.

UNIT 3: Bonding And Elementary Steps In Catalysis 6

Bonding, Bonding To Transition Metal Surfaces, Chemical Bonding In Organometallic Coordination Complexes And On Surfaces of Transition Metal Compounds, Elementary Steps In Organometallic Complexes, Creation of A Vacant Site, Coordination Of The Substrate, Insertions And Migrations, Β-Elimination And Deinsertion, Oxidative Addition, Reductive Elimination, Α-Elimination Reactions, Cyclometallation , Activation Of Substrate Towards Nucleophilic Attach, Σ-Bond Metathesis, Heterolytic Cleavage of Dihydrogen, Elementary Reaction Steps On Surfaces: Metal Catalysed Reactions, Mechanism of The Reaction on Oxides, Catalysis By Solid Acids.

UNIT 4: Heterogeneous Catalysis 6

Synthesis Gas Reactions, Fischer-Tropsch Synthesis of Hydrocarbons, Modification of The Catalyst By Alloying Metals And By Using Promoters And Supports, Hydro-Dehydrogenation Reactions on Metals, Catalytic Oxidation.

UNIT 5: Homogeneous Catalysis With Transition Metal Complexes 6

Rhodium Catalyzed Hydroformylation: Rhodium Based Hydroformylation, Ligand Effects, Phosphine Effects, Ligand Effects In Rhodium Catalyzed Hydroformylation, ,The

Characterization of Intermediates,

Zirconium Catalyzed Polymerization Of Alkenes : Supported Titanium Catalysts ,Isotactic Polypropylene ,The Cossee-Arlman Mechanism , Homogeneous Versus Heterogeneous Catalysts , Site Control Versus Chain-End Control ,Chain-End Control: Syndiotactic Polymers , Chain-End Control: Isotactic Polymers ,Sitecontro1: Recent history Site Control: Isotactic Polymers

Asymmetric Hydrogentation: Cinnamic Acid Derivatives , Naproxenandibuprofen , Binapcatalysis

UNIT 6: Preparation of Catalyst Supports And Zeolites 6

Introduction ,Preparation of Silica Gel Catalyst Supports , Preparation of Silica Gel , Preparation of Alumina Catalyst Supports , Preparation of $\gamma - Al_2O_3$ and $\eta - Al_2O_3$, Structure of $\gamma - Al_2O_3$ And $\eta - Al_2O_3$,Zeolite Synthesis , Synthesis of Zeolite A , Synthesis of Zeolite Y , Synthesis of Mordenite , Synthesis of ZSM-5 , Catalyst Shaping: Introduction , Spray Drying ,Granulation , Pelletization , Extrusion , Oil-Drop Method/Sol-Gel Method .

UNIT 7: Preparation of Supported Catalysts 3

Introduction, Selective Removal, Application On A Separately Produced Support, Support Surface Chemistry, Impregnation, Deposition-Precipitation.

UNIT 8: Catalyst Characterization With Spectroscopic Techniques 4

Introduction ,Aim of Catalyst Characterization ,X-Ray Diffraction (XRD) ,Electron Microscopy ,Temperature Programmed Techniques ,Surface Spectroscopy ,Infrared Spectroscopy ,Extended X-Ray Absorption Fine Structure (Ems) ,Techniques , Mossbauer Spectroscopy.

UNIT 9: The Use of Adsorption Methods For The Assessment of The Surface Area And Pore Size Distribution of Heterogeneous Catalysts 3

Introduction ,Physical Adsorption, Adsorption Isotherms , Classification of Pore Sizes , Porosity of Porous Substances , The Yardstick In The Determination of Surface Areas , The Langmuir Adsorption Isotherm (Monolayer Adsorption) And The Bet Equation (Multilayer Adsorption) ,The Concept of A Standard Isotherm ; The T Method , Micro-porosity , Hysteresis Loops , The Corrected Kelvin Equation.

Text Book

1. J.A. Moulijn, J. A., Leeuwen, P.W.N.M. V. and Santen, R.A. V., 1993, “Studies in Surface Science and Catalysis Vol. 79: CATALYSIS: An Integrated Approach to Homogeneous, Heterogeneous and Industrial Catalysis”, Elsevier, Netherlands.

2 year M. Tech Course Curricula for Chemical Engineering							
M. Tech IV semester							
S. N.	**Course Code**	**Course Title**	**Type**	**L**	**T**	**P**	**Credits**
1.	14M1GCL43x	Elective-V	Elective	3	0	0	3
2.	14M1GCL43x	Elective-VI	Elective	3	0	0	3
3.	14M19CL491	Project Seminar	Core	0	0	4	2
4.	14M19CL492	Thesis	Core	0	0	28	14
			Sub Total				**22**
			Total Credits =				**76**

Course Description

Title of Course: Process Engineering **Course Code: 14M1GCL431**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

This course deals study and analysis of product and process development like creative and assessing the primitive design problem, creating flow sheet, synthesis of reactor-separation trains.

Course outcome

At end of the course students should be able create new ideas, process flow sheets and simulate them using simulation tools to meet the design requirement.

Course Contents

UNIT 1: Product and Process Invention 4

Objectives, design Opportunities, steps in product and process design, environmental protection, safety considerations, engineering ethics, role of computers

UNIT 2: Molecular Structure Design 3

Objectives, Introduction, Property Estimation, Optimization to locate molecular structure

UNIT 3: Process Creation 5

Preliminary database creation ,Preliminary process synthesis, Development of base case design, Generalization of the Resolution Based Synthesis procedure for development of flow sheet for a chemical plant,

UNIT 4: Simulation to assist in process creation 3

Principles of steady state flow sheet – simulation, principles of batch process simulation

UNIT 5: Heuristics for process synthesis 3

Raw materials and chemical reactions, distribution of chemicals, separations, heat removal from and addition to reactors, heat exchangers and furnaces, pumping, compression, pressure reduction, vacuum, and conveying of solids

UNIT 6: Reactor Design and Reactor Network Synthesis 7

Reactor models, Stoichiometry, extent of reaction, equilibrium, kinetics, ideal kinetic reaction models – CSTRs and PFRs, reactor design for complex configurations, reactor design using the attainable region

UNIT 7: Synthesis of Separation Trains 10

Feed separation systems, phase separation of reactor effluent, industrial separation operations, criteria for selection of separation methods, selection of equipment, sequencing of ordinary distillation columns for the separation of nearly ideal fluid mixtures, Sequencing of operations for the separation of non-ideal fluid mixtures, separation systems for gas mixtures, separation sequencing for solid-fluid systems

UNIT 8: Heat and Power Integration 7

Minimum utility targets, networks for maximum energy recovery, minimum number of heat exchangers, threshold approach temperature, optimal approach temperature, Heat integrated distillation trains

Text Book

1. Seider, W. D., Seader, J.D., Lewin, D. R., Widagdo, S., 2008, “Product & Process Design Principles Synthesis Analysis & Evaluation”, 3rd Ed., John Wiley & Sons, New York.

Reference Books

1. Douglas, J.M., 1988, “Conceptual Design of Chemical Processes”, 1st Ed, McGraw-Hill, New York.
2. Kumar, A., 1981, “Chemical Process Synthesis & Engineering Design”, McGraw-Hill, New Delhi.
3. Rudd, D. F. and Watson, C.C., 1968, “Strategy of Process Engineering”, John Wiley& Sons, New York.
4. Murphy, R., 2005, Introduction to Chemical Processes: Principles, Analysis, Synthesis”, 1st Ed, McGraw-Hill, New York.
5. Smith, R. M., 2005, “Chemical Process Design & Integration”, John Wiley & Sons, New York.
6. Kemp, I.C., 2007, “Pinch Analysis and Process Integration, Second Edition: A User Guide on Process Integration for the Efficient Use of Energy”, 2nd Ed., Butterworth-Heinemann.

Course Description

Title of Course: Conceptual Design of Selected Separation Process **Course Code: 14M1GCL432**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

The aim of the course is to provide basic idea about the design of some important separation processes in chemical industry.

Course outcome

At end of the course students should be able analyse economic feasibility and therefore design chemical and mechanical aspects of various types of separation process.

Course Content

UNIT 1: Strategy for process synthesis and analysis **8**

Creative aspects of process design, a hierarchical approach to conceptual design

UNIT 2: Engineering economics **10**

Cost information required, estimating capital and operating cost, total capital investment and total product cost, time value of money, measures of process profitability

UNIT 3: Developing a conceptual design and finding best flow sheet: **12**

Input information and batch versus continuous, Input output structure of the flow sheet: design variable, overall material balance and stream costs, process alternatives, recycle structure of the flow sheet: recycle material balance, heat effects, equilibrium limitation, recycle economical and cost

UNIT 4: Design of chemical processes **12**

Design of distillation tower, Azeotropic system, solvent extraction, membrane separation, reactive distillation, absorption

Text Books:

1. B. K. Dutta, Principles of Mass Transfer and Separation Processes, Prentice Hall of India Private Limited, 2007.
2. James M douglas: conceptual design of chemical process, Mcgraw Hill Book company

Course Description

Title of Course: Safety & Hazards Analysis and Assessment **Course Code: 14M1GCL433**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

The purpose of this course is to familiarize with safety, health and Hazard issues in the operation of a chemical plant.

Course outcome

After the completion of this course, student will be aware with the steps taken in a chemical plant to safeguard the human resource, plant resource.

Course Content

UNIT 1: Introduction and Concepts of Safety **6**

Definitions. Types of Accidents. Causes and direct & indirect effects of accidents, Types of damages. Role of safety considerations in chemical plant design & operations. Protective & safety equipment's. Measure of Risk. Liabilities of accidents Laws. Rules, Regulations (concerning safety in chemical process plant) for the prevention of accident. Managerial aspects of safety, General aspects of post disaster mitigation and management within an organization & in society at large.

UNIT 2: Toxicology and industrial hygiene **8**

Typical toxins and their biological effects. Outline of their ingestion to and elimination from biological systems. Toxicological Parameters -Their definitions and outline of the measurement methods. Evaluation of exposure to toxicants and its impact. Source Models - Release & flow of toxic gases & liquids, flashing liquids, boiling liquids, etc. Dispersion Models - factors affecting dispersion and their modeling. Design & Equipment for prevention of toxic release in chemical plants. Management of toxic release scenario.

UNIT 3: Fires and explosion **8**

The fire triangle and factors contributing to fire & explosions. Definition. Relevant material characteristics & properties. Concepts of Ignition, Ignition Energy. Phenomena and Source of Ignition auto ignition, auto oxidation, adiabatic compression, electrostatic ignition, role of fuel sprays, mists, dusts on ignition process. Explosions - various types & conditions for their occurrence. Inerting & Purging of equipment, Ventilation of rooms, Control of static electricity process control systems, Sprinkler systems, Firefighting systems

UNIT 4: Relief and relief systems: **4**

Definitions. Relief requiring scenarios. Relief types & locations. Relief systems, various options and their sizing and applications for single and multiphase flows. Deflagration venting for dust & vapour explosions.

UNIT 5: Hazard identifications: **6**

HAZOP, HAZAN and such methods. Safety Review & other methods, examples. Safety Audit.

UNIT 6: Risk assessment: **6**

Review of probability theory in respect of failures, coincidences etc. Leading to unsafe situation. Concepts of event trees & fault trees. Analysis of trees for risk assessment, its advantages & disadvantages for simple examples of application of Risk Assessment technique.

UNIT 7: Accident investigations: **4**

Learning from accidents Methods of investigating and diagnosing. Aids for recommending case studies of well-known accidents such as Flixburough. Bhopal etc.

Text Books:

1. Crowl, D. Y., Louvar, J. F., "Chemical Process Safety Fundamentals with Applications", Prentice Hall, Englewood, 1990.
2. Pandya, C. L., "Hazards in Chemical Units", Oxford ISH 1991.
3. Pandya, C. L., "Risk in Chemical Units" Oxford IBH 1994.

Course Description

Title of Course: Nanotechnology & Applications **Course Code: 14M1GCL434**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

The aim of the course is to provide core aspects of the physical sciences which are relevant to nanotechnology e.g. Electronic, optical, magnetic, structural and chemical properties.

Course outcome

At end of the course students should be able to identify various types of nano material and their Excellency in different industrial applications.

Course Content

UNIT 1: Introduction to nanotechnology **12**

Definition, history of nanotechnology. Properties in nanoscale: Extensive and Intensive properties, change in physical properties like colour, melting point, electrical, magnetic, and mechanical. Crystal structure; free electron theory of metals; band theory of solids; metals and insulators; semiconductors: classification, electrons and holes, transport properties; size and dimensionality effects - quantum wells.

UNIT 2: Synthesis of nano materials **12**

Synthesis of nano materials, different approaches of synthesis (physical techniques and Chemical Techniques. Equipment and processes needed to fabricate nano devices and structures.

UNIT 3: Thin Films and Thick Films **6**

Deposition of thin film and thick films, Physical vapour Deposition (PVD) and Chemical Vapour Deposition

UNIT 4: Characterization techniques of nano-materials **4**

SEM, STM, AFM, XRD etc. Electronic, Magnetic, Optical, Chemical and Mechanical properties of nano materials.

UNIT 5: Applications of different nano-materials in Chemical and Environmental engineering **12**

Discovery, preparation, properties, applications of carbon nanotubes. Inorganic nanowires, Biological and bio-inspired materials, Metallic nano materials, Different shape nano materials. Nanomaterial based biosensors: bio functionalization of nano materials, advantages over other sensors, Field effect transistor based biosensors. Application in cholesterol, blood sugar, single virus detection: Semiconductor nanoparticles and Quantum dots. Application of quantum dots. Application of nanoparticles in catalysis.

Text Books:

1. Introduction to Nanotechnology, Poole, Charles P. Owens, Frank J., New York: John Wiley & Sons, 2003. Nanotechnology basic science and emerging technologies by Kannangar, UNI of NSW Press.

2. M.Di Ventra, S.Evoy and Jr. J. R. Heflin, Introduction to Nanoscale Science and Technology, (Eds.), Springer, 2004.

3. Jr. C. P. Poole, F. J. Owens, Introduction to Nanotechnology, Wiley, 2003.

Elective VI

Course Description

Title of Course: Advanced Process Synthesis **Course Code: 14M1GCL435**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

This course deals with detailed synthesis of process flow sheets using computational packages like CHEMCAD, ASPEN PLUS etc. It also deals with optimization of process flow sheets and control analysis.

Course Outcome

Students will get expertise in process synthesis and analysis.

Course Contents

UNIT 1: Heuristics for Process Synthesis 5

Objectives, Introduction, Raw Materials and Chemical Reactions, Distribution of Chemicals: Inert species, purge streams, recycle to extinction, selectivity, Reactive Separations, Optimal conversion, Separations: separation involving liquid and vapor, mixtures, separation involving solid particles, heat removal from and addition to reactors, heat exchanger and furnaces, pumping, compression, pressure reduction, vacuum, and conveying of solids, changing the particle size of solids and size separation of particles, removal of particles from gases and liquids.

UNIT 2: Reactor Design and Reactor Network Synthesis 5

Reactor design for complex configuration, reactor network design using the attainable region, construction of the attainable region, the principles of reaction invariants.

UNIT 3: Synthesis of separation trains 8

Sequencing of operations for the separation of non-ideal fluid mixtures, Heuristics for determining favourable sequences, complex and thermally coupled distillation columns, sequencing of operation for the separation of Non ideal fluid mixtures: azeotropy, residue curves, computing azeotropes for multi component mixtures, heterogeneous distillation, pressure swing distillation, membranes, absorbers, auxiliary separators, reactive distillation, separation train synthesis, Separation systems for gas mixtures, separation sequencing for solid-fluid systems.

UNIT 4: Reactor- separator-recycle networks 7

Introduction, locating the separation section with respect to the reactor section, trade off in processes involving recycle.

UNIT 5: Heat and Power Integration 6

Network for maximum energy recovery: mixed integer linear programming, Minimum number of heat exchangers: stream splitting, Optimal temperature approach, superstructures for minimization of annual costs, Heat integrated distillation trains: impact of operating pressure, multiple effect distillation, heat engines and heat pumps: positioning heat engines and heat pumps, optimal design.

UNIT 6: Mass Integration 5

Introduction, minimum mass separating agents: approach to phase equilibrium, concentration interval method, composite curve methods, mass exchange networks for minimum external mass separating agents, minimum number of mass exchangers, breaking mass loops.

UNIT 7: Optimization of process flow sheets 4

Introduction, general formulation of the optimization, classification of optimization problems, linear programming, nonlinear programming, optimization algorithm, flow sheet optimization: case studies.

UNIT 8: Integration of process design and process control 3

Introduction, control system configuration, classification of process variables, selection of controlled output variables, selection of manipulated variables, selection of measured variables, degree of freedom analysis, qualitative plant wide control system, qualitative plant wide control system synthesis.

Text book

1. Seider, W. D., Seader, J.D. ,Lewin, D. R., Widagdo, S., 2008, “Product & Process Design Principles Synthesis Analysis & Evaluation”, 3rd Ed., John Wiley & Sons, New York

Reference Books

1. Rudd, D.F., Powers, G.J., and Siirola, J.J., 1973, “Process Synthesis", Prentice Hall, Englewood Cliffs, N.J...

2. Floudas, C.A., 1995, "Nonlinear and Mixed Integer Optimization: Fundamentals and Applications", Oxford University Press, New York.

3. Shenoy, U.V., 1995,"Heat Exchange Network Synthesis: Process Optimization by Energy and Resource Analysis", Gulf Publishing Company, Houston, Texas.

4. Douglas, J.M., 1988, “Conceptual Design of Chemical Processes”, 1st Ed, McGraw-Hill, New York.

5. Kumar, A., 1981, “Chemical Process Synthesis & Engineering Design”, McGraw-Hill, New Delhi

6. Rudd, D. F. and Watson, C.C., 1968, “Strategy of Process Engineering”, John Wiley& Sons, New York.

7. Murphy, R., 2005, Introduction to Chemical Processes: Principles, Analysis, Synthesis", 1st Ed, McGraw-Hill, New York.

8. Smith, R. M., 2005, "Chemical Process Design & Integration", John Wiley & Sons, New York.

9. Kemp, I.C., 2007, "Pinch Analysis and Process Integration, Second Edition: A User Guide on Process Integration for the Efficient Use of Energy", 2nd Ed., Butterworth-Heinemann.

Course Description

Title of Course: Bioprocess Principles **Course Code: 14M1GCL436**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

This course deals study and analysis of product and process development like creative and assessing the primitive design problem, creating flow sheet, synthesis of reactor-separation trains.

Course outcome

At end of the course students should be able create new ideas, process flow sheets and simulate them using simulation tools to meet the design requirement.

Course Contents

UNIT 1: Introduction **10**

Fermentation processes, general requirements of fermentation processes, an overview of aerobic and anaerobic fermentation processes and their application in industry, Medium requirements for fermentation processes - examples of simple and complex media, Design and usage of commercial media for industrial fermentation. Sterilization: Thermal death kinetics of micro-organisms, Batch and Continuous Heat-Sterilization of liquid Media, Filter Sterilization of Liquid Media and Air.

UNIT 2: Enzyme technology **12**

Enzymes: Classification and properties, Applied enzyme catalysis, Kinetics of enzyme catalytic reactions, Microbial metabolism, Metabolic pathways, Protein synthesis in cells. Stoichiometry and Kinetics of substrate utilization and Biomass and product formation: Stoichiometry of microbial growth, Substrate utilization and product formation-Batch and Continuous culture, Fed batch culture Recovery and purification of products.

UNIT 3: Bioreactor **12**

Bioreactor and product recovery operations: Operating considerations for bioreactors for suspension and immobilized cultures, Selection, scale-up, operation of bioreactors – Mass transfer in heterogeneous biochemical reaction systems; Oxygen transfer in submerged fermentation processes; oxygen uptake rates and determination of oxygen transfer rates and coefficients; role of aeration and agitation in oxygen transfer. Heat transfer processes in biological systems.

UNIT 4: Control in Bioprocesses **8**

Introduction to Instrumentation and Process Control in Bioprocesses: Measurement of physical and chemical parameters in bioreactors - Monitoring and control of dissolved oxygen, pH, impeller speed and temperature in a stirred tank fermenter.

TEXT BOOKS:

1. Shuler, M. L., and Kargi, F., 2002, “Bio-process engineering", 2nd Edition, Prentice Hall of India, New Delhi.

2. Bailey, J. E., and Ollis, D. F., 1986, “Biochemical Engineering Fundamentals", 2nd Ed., McGraw-Hill Publishing Co. New York.

REFERENCE:

1. Stanbury, P., Whitakar, A., and Hall, S. J., 1999, "Principles of Fermentation Technology" 2nd Ed., Elsevier-Pergamon.

Course Description

Title of Course: Bio- separations **Course Code: 14M1GCL437**
L-T-P Scheme: 3-0-0 **Course Credits: 3**

Course Objective

This course deals study and analysis of product and process development like creative and assessing the primitive design problem, creating flow sheet, synthesis of reactor-separation trains.

Course outcome

At end of the course students should be able create new ideas, process flow sheets and simulate them using simulation tools to meet the design requirement.

Course Contents

UNIT 1: Introduction 2

Bio separations: an overview, Analytical methodologies, separation and purification methods.

UNIT 2: Purification and Analysis by HPLC 12

Analysis of protein impurities in pharmaceuticals derived from recombinant DNA, Basic chromatographic terms and concepts, the chemical structure of polypeptide and protein, Physicochemical Factors That Underpin Ligate Interactions with Polypeptides and Proteins in HPLC Separation Systems , Strategic Considerations behind the HPLC Separations, Specific Physicochemical Considerations on the Individual Chromatographic Modes, The Effect of Temperature and the Thermodynamics of Polypeptide- or Protein-Ligate Interactions

UNIT 3: Capillary Electrophoresis of Compounds of Biological Interest 7

Introduction, Capillary Zone Electrophoresis, Migration Behaviour of Peptides and Proteins, Modifications of Fused Silica Capillaries, Effect of Temperature on Separations, Strategy for Protein Separations, Capillary Gel Electrophoresis, Micellar Electro kinetic Chromatography, Capillary Electro chromatography

UNIT 4: Processing Plants and Equipment 7

Introduction, Industries Using Bio separations, Process-Scale Bio separations, Process-Scale Considerations

UNIT 5: Process Control of Bio separation Processes 8

Need for Process Control in Bio separations, Brief Overview of Current Control Methods, Application Examples, Opportunities for Continuing Development

UNIT 6: Economics of Bio separation Processes 6

Drugs Market and Sales, Applications of Models and Flow Sheets in Bio separation Economics

Text Book

1. S, Ahuja, "Handbook of Bio separations", volume 2, Academic Press.