NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

SCHEME OF INSTRUCTION AND SYLLABI
FOR M.TECH PROGRAM
(COMPUTER AIDED PROCESS AND EQUIPMENT DESIGN)

Effective from 2014-15

DEPARTMENT OF CHEMICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

VISION

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society.

MISSION

- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.
- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.

DEPARTMENT OF CHEMICAL ENGINEERING

VISION

To attain global recognition in research and training students for meeting the challenging needs of chemical & allied industries and society.

MISSION

- Providing high quality education in tune with changing needs of industry.
- Generating knowledge and developing technology through quality research in frontier areas of chemical and interdisciplinary fields.
- Fostering industry-academia relationship for mutual benefit and growth.

GRADUATE ATTRIBUTES

The Graduate Attributes are the knowledge, skills and attitudes which the students have at the time of graduation. These attributes are generic and are common to all engineering programs. These Graduate Attributes are identified by National Board of Accreditation.

1. Scholarship of Knowledge: Acquire in-depth knowledge of specific discipline or professional area, including wider and global perspective, with an ability to discriminate, evaluate, analyze and synthesize existing and new knowledge, and integration of the same for enhancement of knowledge.
2. Critical Thinking: Analyze complex engineering problems critically, apply independent judgment for synthesizing information to make intellectual and/or creative advances for conducting research in a wider theoretical, practical and policy context.
3. Problem Solving: Think laterally and originally, conceptualize and solve engineering problems, evaluate a wide range of potential solutions for those problems and arrive at feasible, optimal solutions after considering public health and safety, cultural, societal and environmental factors in the core areas of expertise.
4. Research Skill: Extract information pertinent to unfamiliar problems through literature survey and experiments, apply appropriate research methodologies, techniques and tools, design, conduct experiments, analyze and interpret data, demonstrate higher order skill and view things in a broader perspective, contribute individually/in group(s) to the development of scientific/technological knowledge in one or more domains of engineering.
5. Usage of modern tools: Create, select, learn and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modeling, to complex engineering activities with an understanding of the limitations.
6. Collaborative and Multidisciplinary work: Possess knowledge and understanding of group dynamics, recognize opportunities and contribute positively to collaborative-multidisciplinary scientific research, demonstrate a capacity for self-management and teamwork, decision-making based on open-mindedness, objectivity and rational analysis in order to achieve common goals and further the learning of themselves as well as others.
7. Project Management and Finance: Demonstrate knowledge and understanding of engineering and management principles and apply the same to one's own work, as a member and leader in a team, manage projects efficiently in respective disciplines and multidisciplinary environments after consideration of economical and financial factors.
8. Communication: Communicate with the engineering community, and with society at large, regarding complex engineering activities confidently and effectively, such as, being able to comprehend and write effective reports and design documentation by adhering to appropriate standards, make effective presentations, and give and receive clear instructions.
9. Life-long Learning: Recognize the need for, and have the preparation and ability to engage in life-long learning independently, with a high level of enthusiasm and commitment to improve knowledge and competence continuously.
10. Ethical Practices and Social Responsibility: Acquire professional and intellectual integrity, professional code of conduct, ethics of research and scholarship, consideration of the impact of research outcomes on professional practices and an understanding of responsibility to contribute to the community for sustainable development of society.
11. Independent and Reflective Learning: Observe and examine critically the outcomes of one's actions and make corrective measures subsequently, and learn from mistakes without depending on external feedback.

DEPARTMENT OF CHEMICAL ENGINEERING

M.TECH IN CHEMICAL ENGINEERING

(COMPUTER AIDED PROCESS AND EQUIPMENT DESIGN)

PROGRAM EDUCATIONAL OBJECTIVES

PEO1.	Pursue successful industrial, academic and research careers in specialized fields of Chemical Engineering.
PEO2.	Apply the knowledge of advanced topics in Chemical Engineering to meet contemporary needs of industry and research.
PEO3.	Use modern software tools for design of processes and equipment.
PEO4.	Identify issues related to ethics, society, safety, energy and environment in the context of Chemical Engineering applications.
PEO5.	Pursue self-learning to remain abreast with latest developments for continuous professional growth.

Mapping of Departmental Mission statements with Program Educational Objectives

Mission Statement	PEO1	PEO2	PEO3	PEO4	PEO5
Providing high quality education in tune with changing needs of industry.	3	3	3	2	-
Generating knowledge and developing technology through quality research in frontier areas of chemical and interdisciplinary fields.	3	2	2	1	-
Fostering industry-academia relationship for mutual benefit and growth.	3	2	2	-	2

1: Slightly 2: Moderately 3: Substantially

Mapping of Program Educational Objectives with Graduate Attributes

PEO	GA1	GA2	GA3	GA4	GA5	GA6	GA7	GA8	GA9	GA10	GA11
PEO1	3	3	3	3	3	3	3	3	3	3	2
PEO2	2	1	3	3	2	2	1	-	-	-	-
PEO3	2	1	3	1	3	2	2	-	-	-	1
PEO4	2	3	2	1	-	-	-	-	2	3	2
PEO5	2	-	2	2	1	-	-	2	3	2	3

PROGRAM OUTCOMES: At the end of the program, the student will be able to:

PO1	Model chemical engineering processes including multi-component mass transfer, multi-phase momentum transfer and multi-mode heat transfer from advanced engineering perspective.
PO2	Apply modern experimental, computational and simulation tools to address the challenges faced in chemical and allied engineering industries.
PO3	Implement techniques for minimizing cost and energy requirements in chemical plants.
PO4	Design measures to take care of environment, health and safety issues pertaining to chemical industries.
PO5	Communicate effectively and demonstrate leadership skills
PO6	Carry out research work independently and innovate novel processes and products
PO7	Practice professional ethics
PO8	Pursue life-long learning as a means of updating knowledge and skills.

Mapping of Program Outcomes with Program Educational Objectives

	PEO1	PEO2	PEO3	PEO4	PEO5
PO1	3	3	-	-	2
PO2	3	3	3	-	2
PO3	3	3	2	2	2
PO4	2	2	1	3	2
PO5	2	-	-	2	2
PO6	2	2	2	2	3
PO7	2	-	-	3	-
PO8	2	2	1	2	3

CURRICULAR COMPONENTS

Degree Requirements for M. Tech in Chemical Engineering

Category of Courses	Credits Offered	Min. credits to be earned
Program Core Courses (PCC)	38	38
Departmental Elective Courses (DEC)	15	15
Dissertation	26	26
Total	**79**	**79**

SCHEME OF INSTRUCTION

M.Tech. (Chemical Engineering) Course Structure

I - Year I - Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	CH5101	Advanced Transport Phenomena	4	0	0	4	PCC
2	CH5102	Advanced Reaction Engineering	4	0	0	4	PCC
3	CH5103	Chemical Process Synthesis	4	0	0	4	PCC
4	CH5104	Chemical Process Modeling	4	0	0	4	PCC
5		Elective – I	3	0	0	3	DEC
6		Elective – II	3	0	0	3	DEC
7	CH5105	Computer Aided Design of Process Equipment Laboratory	0	0	3	2	PCC
8	CH5141	Seminar	0	0	2	1	PCC
		TOTAL	**22**	**0**	**5**	**25**	

I - Year II - Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	CH5151	Optimization of Chemical Process	4	0	0	4	PCC
2	CH5152	Computer Control of Process Plants	4	0	0	4	PCC
3	CH5153	Steady State Process Simulation	4	0	0	4	PCC
4		Elective – III	3	0	0	3	DEC
5		Elective – IV	3	0	0	3	DEC
6		Elective – V	3	0	0	3	DEC
7	CH5154	Computer Aided Process Synthesis and Simulation Laboratory	0	0	3	2	PCC
8	CH5191	Seminar	0	0	2	1	PCC
		TOTAL	**21**	**0**	**5**	**24**	

II - Year I - Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	CH6142	Comprehensive Viva-voce	0	0	0	4	PCC
2	CH6149	Dissertation Part-A	0	0	0	8	
		TOTAL	**0**	**0**	**0**	**12**	

II - Year II - Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
2	CH6199	Dissertation Part-B	0	0	0	18	PCC
		TOTAL	**0**	**0**	**0**	**18**	

List of Electives

I Year I Semester

CH5111 Advanced Heat Transfer

CH5112 Risk Analysis and Hazops

CH5113 Statistical Design of Experiments

CH5114 Multi-phase Flow

CH5115 Project Evaluation

CH5116 Conceptual Design of Chemical Processes

I Year II Semester

CH5161 Membrane Separation Techniques

CH5162 Advanced Mass Transfer

CH5163 Energy Management

CH5164 Pinch Technology

CH5165 Reactive Separations

CH5166 Process Intensification

CH5167 Process Integration

CH5168 Strategy of Process Engineering

CH5169 Bioprocess Engineering

CH5101	ADVANCED TRANSPORT PHENOMENA	PCC	4 – 0 – 0	4 Credits

Pre-requisites: None

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

CO1	Understand the analogous mechanism of momentum, heat and mass transport for steady and unsteady flow.
CO2	Perform momentum, energy and mass balances for a given system at macroscopic and microscopic scale.
CO3	Solve the governing equations to obtain velocity, temperature and concentration profiles.
CO4	Model the momentum, heat and mass transport under turbulent conditions.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	3	-	-	-	-	-	-	-
CO2	3	2	-	-	-	-	-	-
CO3	3	2	-	-	-	-	-	-
CO4	3	1	-	-	-	-	-	-

Detailed syllabus

Equations of Change for Isothermal Systems: Equation of Continuity, Equation of Motion, Equation of Mechanical Energy, Equations of Change in terms of the Substantial Derivative, Use of the Equations to solve Flow Problems, Dimensional Analysis of the Equations of Change.

Velocity Distributions with more than one Independent Variable: Time Dependent Flow of Newtonian Fluids.Velocity Distributions in Turbulent Flow -Comparisons of Laminar and Turbulent Flows, Time Smoothed Equations of Change for Incompressible Fluids, Time Smoothed Velocity Profile near a wall, Empirical Expressions for the Turbulent Momentum Flux, Turbulent Flow in Ducts, Turbulent Flow in Jets.

Macroscopic Balances for Isothermal Systems: The Macroscopic Mass Balance, The Macroscopic Momentum Balance, The Macroscopic Mechanical Energy Balance, Estimation of the Viscous loss, Use of the Macroscopic Balances for Steady-State Problems, Derivation of the Macroscopic Mechanical Energy Balance.

Equations of Change for Non-Isothermal Systems - The Energy Equation, Special forms of the Energy Equation, The Boussinesq Equation of Motion for Forced and Free Convection, Use of the Equations of change to Solve Steady-State Problems, Dimensional Analysis of the Equations of Change for Non-Isothermal Systems,

Temperature Distributions in Solids and in Laminar Flow: Heat Conduction with an Electrical Heat Source, Heat Conduction with a Viscous Heat Source. Temperature Distributions with more than One Independent Variable - Unsteady Heat Conduction in Solids, Steady Heat Conduction in Laminar, Incompressible Flow. Temperature Distributions in Turbulent Flow - Time-Smoothed Equations of Change for Incompressible Non-Isothermal Flow, Time-Smoothed Temperature Profile near a Wall, Empirical Expressions for the Turbulent Heat Flux Temperature Distribution for Turbulent Flow in Tubes,

Macroscopic Balances For Non-Isothermal Systems: Macroscopic Energy Balance, Macroscopic Mechanical Energy Balance, Use Of The Macroscopic Balances To Solve Steady State Problems With Flat Velocity Profiles,

Concentration Distributions in Solids and in Laminar Flow: Shell Mass Balances Boundary Conditions, Diffusion through a Stagnant Gas Film, Diffusion with a Heterogeneous Chemical Reaction. Concentration Distributions with more than One Independent Variable: Time-Dependent Diffusion, Steady-State Transport in Binary Boundary Layers, Concentration Distributions in Turbulent Flow - Concentration Fluctuations and the Time-Smoothed Concentration, Time-Smoothing of the Equation of Continuity of A, Semi-Empirical Expressions for the Turbulent Mass Flux, Enhancement of Mass Transfer by a First-Order Reaction in Turbulent Flow

Interphase Transport in Multi-Component Systems: Definition of Transfer Coefficients in One Phase, Analytical Expressions for Mass Transfer Coefficients, Correlation of Binary Transfer Coefficients in One Phase, Definition of Transfer Coefficients in Two Phases, Mass Transfer and Chemical Reactions

Macroscopic Balances For Multi-Component Systems: Macroscopic Mass Balances, Macroscopic Momentum, Use of the Macroscopic Balances to solve Steady-State Problems

Reading:

1. Bird R. B., Stewart W. E. and Light Foot E. N., Transport Phenomena, Revised 2nd Edition, John Wiley & Sons, 2007.
2. Geankopolis C. J., Transport Processes and Unit Operations, 4th Ed., Prentice Hall (India) Pvt. Ltd., New Delhi. 2004.
3. Thomson W. J., Transport Phenomena, Pearson education, Asia, 2001.

CH5102	ADVANCED REACTION ENGINEERING	PCC	4 – 0 – 0	4 Credits

Pre-requisites: None

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

CO1	Calculate reactor performance in situations where the observed reaction rate is significantly influenced by internal mass transfer in porous heterogeneous catalytic systems
CO2	Understand the energy balance and concentration profiles of multiphase reactors.
CO3	Estimate the performance of multiphase reactors in the situation such as temperature not uniform within the reactor and three phases are involved
CO4	Understand modern reactor technologies for mitigation of global warming

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	3	-	-	-	-	-	-	-
CO2	2	2	-	-	-	-	-	-
CO3	3	1	-	-	-	-	-	-
CO4	3	2	-	3	-	-	-	-

Detailed syllabus

Non elementary Kinetics Importance: Approximations for formulations of Rate laws, Formulations of Kinetic model.

Effect of flow on conversions in Reactors: Semibatch Reactors : Importance and examples of applications , Material Balance on Semibatch Reactor, Multiple reaction in Semibatch Reactors, Conversion Vs Rate in Reactors, Use of POLYMATHS to solve the equations and understanding the profiles

Non-Isothermal reaction modeling in CSTR & Semi-Batch reactor: Energy Balance equations for CSTR, PFR and Batch reactors, Adiabatic operations Temperature conversion profiles in PFR, CSTR, Steady state tubular reactor with heat exchange,

Need for Multi-staging CSTR with multiple stages: Exothermic and Endothermic Reaction with examples, CSTR with heat effects, Multiple reactions in CSTR and PFR with heat effects, Semi batch Reactors with heat exchange.

Design of PFR and Packed Bed Tubular Reactors: Radial and Axial mixing in Tubular reactors, Unsteady state in non isothermal energy balance, CSTR, Energy balance in Batch Reactors, Volume of reactors calculations for non isothermal reactors.

Optimal Design of Reactors for Reversible exothermic reactions: Unsteady state non isothermal reactor design, Adiabatic operation in batch, Heat effects in semibatch Unsteady state operation. Autothermal Plug flow reactors and Packed tubular reactors.PFR with interstage cooling.Shift of Energy and material balance lines for reversible reactions in CSTR, Examples of optimal design of PFR and Semibatch and CSTR Exothermic Reactions

Catalytic reactions: theory and modeling: Global rate of reaction, Types of Heterogeneous reactions Catalysis, Different steps in catalytic reactions, Theories of heterogeneous catalysis . Steady State approximation, formulations of rate law Rate laws derived from the PSSH, Rate controlling steps, Eiley-Rideal model, Reforming catalyst example :Finding mechanism consistent with experimental observations Evaluation of rate law parameters, packed beds : Transport and Reactions, Gradients in the reactors : temperature.

Porous media reactors: Mass transfer coefficients, Flow effects on spheres tube and cylinders, External Mass Transfer pore diffusion, structure and concentration gradients Internal Effectiveness Factor Catalytic wall reactor: limiting steps reactions and mass transfer limiting Porous catalyst on tube wall reactors Design of packed bed porous catalytic reactors: Mass transfer limited reactions in Packed bed

Fluidized bed reactor modeling: Geldart Classification of powders, Fixed bed Vs fluidized bed Why fluidized bed, important parameters pressure drop in fixed bed, Class I model Arbitrary Two Region Flow Models, Class II Chemical Reactor: Plug Flow or Mixed Flow Model. Class III Modeling the Bubbling Fluidized Bed Reactor, BFB, The Kunii-Levenspiel bubbling bed model, Gas Flow Around and Within a Rising Gas Bubble in a Fine particle BFB, Reactor performance of BFB.

Application of Population Balance Equations for reactor modeling: Particle size distribution, Distribution Functions in Particle Measuring Techniques, Particle distribution model in colloidal particle synthesis in batch reactor, Moments of Distribution, Nucleation rate based on volumetric holdup versus crystal growth rate.

Reaction engineering and mitigation of Global warming: CO_2 absorption in high pressure water, different techniques of mitigation of CO_2, methods of separations. Recent advancements, automotive monolith catalytic converter example, removal and utilization of CO_2 for thermal power plants.

Reading:

1. Foggler,H.S., Elements of Chemical Reaction Engineering, Prentice Hall of India, 2008.
2. Levenspiel O., Chemical Reaction Engineering, Wiley, 1998.
3. Fromment G.F. and Bischoff K.B., Chemical Reactor Analysis and Design, John Wiley, 2010.

CH5103	CHEMICAL PROCESS SYNTHESIS	PCC	4 – 0 – 0	4 Credits

Pre-requisites: None

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

CO1	Analyze alternative processes and equipment
CO2	Synthesize a chemical process flow sheet that would approximate the real process
CO3	Design best process flow sheet for a given product
CO4	Perform economic analysis related to process design and evaluate project profitability

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	-	1	3	2	-	-	-	-
CO2	2	2	-	-	-	-	-	-
CO3	2	2	3	2	-	-	-	-
CO4	-	-	3	-	-	-	-	-

Detailed syllabus

Synthesis of steady state flow sheet: Introduction, Flow sheets, The problem of steady state flow sheeting, Scope of propositional logic in process synthesis, Propositional logic, Deduction theorem of propositional logic, Resolution-based synthesis procedure, Generation of resolution-based synthesis procedure for development of flow sheet for a chemical plant.

Optimization of flowsheet with respect to heat exchanger network: Introduction, Network of heat exchanger, Some necessary conditions for the existence of an optimal exchanger network, Maximum heat transfer in a single exchanger (rule 1), Hot and cold utilities (rule2), Condition of optimality for the minimum area network, Three special situations in energy transfer, Heat content diagram representation of the network problem, Matching of heat content diagram for minimum network area, Rules of adjustment of the minimum heat exchanger network to find the optimal solution.

Optimization of steady state flow with respect to adjustment of concentration: Introduction, Adjustment of concentration by mixing, The combination of separation and mixing for minimum separation load, The task of separation, Importance of distillation column sequencing, Heuristic rule of removing components one-by-one (rule 1), Heuristic rule of removing components in large excess early (rule 2), Heuristic rule of difficult separation (rule 3), Procedure of optimal sequencing.

Synthesis of Process Flow sheet: Introduction, Mathematical representation of a steady state flow sheet, General semantic equation of equipment, Generalization of the method of synthesis of process flow sheet, Recycle structure of the flow sheet, separation systems.

Safety in Chemical plant design: Introduction, Reliability of equipment, prevention of accidents, Flammability of chemicals, Safety considerations in plant layout, Classification of chemicals and handling problem, Venting of tanks and vessels, Design of safety valves, Safety consideration in reactor design, Leakages, Handling of fluids, Safety in pipeline layout, Dust explosion, Gas explosion, Dust explosion in vessel with a vent, Design of flare system.

Trouble shooting and Hazard analysis: Introduction, Trouble-shooting analysis of equipment and chemical plants, Fault tree analysis of accidents, Simplification of Boolean functions, Probability of Boolean function, Effect of configurations of equipment on production.

Reliability consideration in maintenance policies of a chemical plant: Introduction, Maintenance policies, Reliability of an equipment, Availability and fractional dead time of a single equipment for an irreversible maintenance policy, Availability and fractional dead time of a single equipment for a reversible maintenance policy, Availability and fractional dead time of a pure series and parallel systems, Mean availability of mixed configurations: voting system, Design of high pressure-trip system of fractionators, Optimal thread maintenance policy.

Economic evaluation: Time value of money, Methods for Profitability evaluation, Rate of return, Net Present Worth, Discounted Cash flow analysis.

Reading:

1. Kumar A., Chemical Process Synthesis and Engineering Design, Tata McGraw Hill, 1982.
2. Bieglar L.T, Grossman E.I and Westerberg A.W., Systematic Methods of Chemical Process Design, Prentice Hall Inc.,
3. Douglas J. M., Conceptual Design of Chemical Processes, McGraw Hill International, 1988.
4. Seider W. D., SeaderJ. D. and Lewin D. R., Product and Process Design Principles: Synthesis, Wiley, 2005.

CH5104	CHEMICAL PROCESS MODELING	PCC	4 – 0 – 0	4 Credits

Pre-requisites: None

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

CO1	Model processes by using suitable model building procedures.
CO2	Analyze transport phenomena based models
CO3	Apply different methods for parameters estimation
CO4	Use neural networks for development of process models.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	3	-	-	-	-	-	-	-
CO2	3	-	-	-	-	-	-	-
CO3	-	3	-	-	-	-	-	-
CO4	-	3	-	-	-	-	-	-

Detailed syllabus

Introduction to process modeling: Introduction to concept of modelling, introduction to mathematical models, relevance to design, control and optimization of chemical processes.

Types of models: Types of mathematical models.

The basic modeling approaches: Conservation equations as mathematical models for chemical processes, constitutive equations as part of models.

The transport phenomena models: Momentum, energy and mass transport models.

Population balance models: Population models, RTD models.

Parameter estimation: Parameter estimation techniques in theoretical as well as numerical models.

Neural networks: Neural network models.

Scaling and order reduction.

Reading:

1. Denn M. M., Process Modelling, John Wiley, 1987.
2. Baughman R. D. and Liu Y. A., Neural Networks for Bioprocessing and Chemical Engineering, Academic Press, 1996.
3. Rutherford Aris, Mathematical Modeling, Vol.1, A Chemical Engineer's Perspective (Process Systems Engineering), Academic Press, 1999.
4. Himmelblau D. and Bischoff K. B., Process Analysis and Simulation, John Wiley & Sons Inc., 1968

CH5105	COMPUTER AIDED DESIGN OF PROCESS EQUIPMENT LABORATORY	PCC	0– 0 – 3	2 Credits

Pre-requisites: None

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

CO1	Solve complex chemical engineering problems by applying suitable numerical methods.
CO2	Estimate the thermodynamic properties from implicit equations using C language/MATLAB
CO3	Design the process equipment using C/C^{++} language /MATLAB
CO4	Analyze and formulate a mathematical problem and solve the resulting system of linear set of equations, ODE, PDE using C/C++ programming/MATLAB.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	1	3	2	-	-	-	-	-
CO2	1	2	3	-	-	-	-	-
CO3	1	3	3	-	-	-	-	-
CO4	-	3	3	-	-	-	-	-

Detailed syllabus

Estimation of Properties: Estimation of Physical properties, Estimation of properties of mixtures; Estimation of Thermodynamic properties; Vapor Liquid Equilibria calculations.

Optimal Design of Equipment: Design of Shell and Tube Heat exchangers; Design of Evaporators; Design of Distillation columns; Design of Reactors.

Reading:

Lab Manual.

CH5151	OPTIMIZATION OF CHEMICAL PROCESSES	PCC	4 – 0 – 0	4 Credits

Pre-requisites: None

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

CO1	Formulate optimization problem for a given Chemical process.
CO2	Understand different optimization methods / techniques.
CO3	Solve the optimization problem by choosing suitable optimization method.
CO4	Analyze the solution.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	3	-	-	-	-	-	-	-
CO2	2	-	-	-	-	-	-	-
CO3	3	2	-	-	-	-	-	-
CO4	-	2	-	-	-	-	-	-

Detailed syllabus

The Nature and Organization of Optimization Problems: What Optimization is all about, Why Optimize?, Scope and Hierarchy of Optimization, Examples of applications of Optimization, The Essential Features of Optimization Problems, General Procedure for Solving Optimization Problems, Obstacles to Optimization.

Basic Concepts of Optimization: Continuity of Functions, Unimodal vs multimodal functions, Convex and concave functions, convex region, Necessary and Sufficient Conditions for an Extremum of an Unconstrained Function, Interpretation of the Objective Function in terms of its Quadratic Approximation.

Optimization of Unconstrained Functions: One Dimensional search Numerical Methods for Optimizing a Function of One Variable, Scanning and Bracketing Procedures, Newton and Quasi-Newton Methods of Unidimensional Search, Polynomial approximation methods, How One-Dimensional Search is applied in a Multidimensional Problem, Evaluation of Unidimensional Search Methods.

Unconstrained Multivariable Optimization: Direct methods, Indirect methods – first order, Indirect methods – second order.

Linear Programming and Applications: Basic concepts in linear programming, Degenerate LP's – Graphical Solution, Natural occurrence of Linear constraints, The Simplex methods of solving linear programming problems, standard LP form, Obtaining a first feasible solution, Sensitivity analysis, Duality in linear programming.

Nonlinear programming with constraints The Lagrange multiplier method, Necessary and sufficient conditions for a local minimum, introduction to quadratic programming.

Optimization of Stage and Discrete Processes: Dynamic programming, Introduction to integer and mixed integer programming.

Heat Transfer and Energy Conservation: Optimizing Recovery of Waste Heat, Optimal Shell and Tube Exchanger Design, Optimization of Heat Exchanger networks, Optimization of evaporator design, Boiler / turbo generator system optimization.

Separation Processes: Optimization of liquid-liquid extraction process, Optimal Design and Operation of staged distillation columns.

Chemical Reactor Design and Operation: Formulation of chemical reactor optimization problems, Use of differential calculus in reactor optimization, Use of linear programming to optimize reactor operations, Nonlinear programming applied to chemical reactor optimization.

Reading:

1. Edgar T. F., Himmelblau D. M.AndLasdon L.S., Optimization of Chemical Processes, McGraw Hill, 1st Edition, 2001.
2. Stoecker W. F., Design of Thermal Systems, McGraw-Hill, 3rd Edition, 2011.
3. Rao S. S., 'Engineering Optimization: Theory and Practice', 4th Edition, John Wiley & Sons Ltd., 2009

CH5152	COMPUTER CONTROL OF PROCESS PLANTS	PCC	4 – 0 – 0	4 Credits

Pre-requisites: None

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

CO1	Apply cascade control, feed-forward control, ratio control, time delay compensated controller strategies to chemical processes.
CO2	Design controllers for multivariable loops.
CO3	Understand dynamic behavior of discrete time processes.
CO4	Design discrete controllers for first order and second order processes.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	-	3	-	-	-	-	-	-
CO2	-	3	-	-	-	-	-	-
CO3	3	-	-	-	-	-	-	-
CO4	-	2	-	-	-	-	-	-

Detailed syllabus

Advanced control strategies: Cascade Control, Feed-forward and ratio control, Time delay compensation, Inferential control; Nonlinear control, Adaptive control.

Control of multi input, multi output processes: Process interactions, Control loop interactions; Pairing of controlled and manipulated variables, Singular value analysis, Tuning of multi-loop controllers, Decoupling, Supervisory control.

Digital computer control: Sampling and filtering of continuous measurements, Analog filters, digital filters, Z-Transforms, Development of discrete time models, Dynamic response of discrete time systems, Analysis of sampled data control systems, Stability analysis.

Design of digital controllers: Deadbeat, Dalhin and Vogel-Edgar Algorithms, Digital computer simulation of control systems.

Reading:

1. Seborg D. E., Edgar T. F. and Mellichamp D. A., Process Dynamics and Control, John Wiley and Sons, 2010.
2. Coughnowr D. R. and LeBlanc S., Process Systems Analysis and Control, 3rd Edition, McGraw Hill International, 2011.
3. Stephanopolaus G., Chemical Process Control, Prentice Hall India, 2008.

CH5153	STEADY STATE PROCESS SIMULATION	PCC	4 – 0 – 0	4 Credits

Pre-requisites: None

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

CO1	Understand different approaches to simulation and define the problem for simulation.
CO2	Analyse the problem and identify degrees of freedom and understand the importance of property estimation methods.
CO3	Apply mathematical methods suitable for solving explicit iterative loops, sparse sets of equations, partitioning & precedence ordering and to find best tear stream sets.
CO4	Carry out steady state process simulation using sequential modular approach and equation oriented approach.

Mapping of course outcomes with program outcomes

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**
CO1	3	-	-	-	-	-	-	-
CO2	3	-	-	-	-	-	-	-
CO3	2	2	-	-	-	-	-	-
CO4	2	2	-	-	-	-	-	-

Detailed syllabus

Introduction: Steady-state flowsheeting and the design process, the total design project.

Flowsheeting on the computer: Motivation for development, Developing a simulation model, Approaches to flowsheeting systems-examples.

Solving linear and nonlinear algebraic equations: Solving one equation in one unknown, Solution methods for linear equations, General approaches to solving sets of nonlinear equations, Solving sets of sparse nonlinear equations.

Physical property service facilities: The data cycle, Computerized physical property systems, Physical property calculations.

Degrees of freedom in a flowsheet: Degrees of freedom, Independent stream variables, Degrees of freedom for a stream and a unit, Degrees of freedom for a flowsheet.

The sequential modular approach to flowsheeting: The solution of an example flowsheeting problem, Other features: Handling design specifications, information streams and control blocks,
Convergence of tear streams: Sequential convergence and simultaneous convergence, Partitioning and precedence ordering set of equations and a flowsheet, tearing a flowsheet, Finding the best tear set family.

Flowsheeting by equation solving methods based on tearing: A simple example, An example system based on equation solving, A complex example of selecting decision and tear variables for a flowsheet, Handling the iterated variables.

Simulation by linear methods: Introduction to linear simulation, Application to staged operations, Application to management problem.

Simulation by Quasi-linear approach: Introduction to Quasi-linear methods, Simulation of flows in pipe networks, Application to distillation, Application to multiple reaction equilibrium, Towards process simulation by Quasi-linear methods.

Reading:

1. Westerberg A. W., Hutchison H. P., Motard R. L. and Winter P., Process Flowsheeting, Cambridge University Press, 2011.
2. Benedek P. (Ed), Steady State Flowsheeting of Chemical Plants, Elsevier Scientific Publishing Co., 1980.
3. Babu B. V., Process Plant Simulation, Oxford University Press, 2004.

CH5154	COMPUTER AIDED PROCESS SYNTHESIS AND SIMULATION LABORATORY	PCC	0 – 0 – 3	2 Credits

Pre-requisites: None

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

CO1	Carry out thermodynamic property estimations using property estimation and property analysis in Aspen
CO2	Simulate and design individual Mixer, splitter, heat exchangers, pumps, compressors, flash units, reactors, distillation columns, calculator block, duplicator, multiplier models.
CO3	Simulate processes involving multiple units and apply sensitivity, design specifications and case study tools in Aspen.
CO4	Simulate and optimize process flowsheets including streams containing solids using sequential modular approach as well as equation oriented approach.
CO5	Carry out dynamic simulation, pinch analysis and cost estimation.
CO6	Design heat exchanger using Exchanger design and rating and distillation column using RADFRAC models.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	1	3	-	-	-	-	-	-
CO2	1	3	-	-	-	-	-	-
CO3	-	3	-	-	-	-	-	-
CO4	-	3	-	-	-	-	-	-
CO5	-	3	2	-	-	-	-	-
CO6	1	3	-	-	-	-	-	-

Detailed syllabus

Solve the following steady state simulation exercises using Aspen software:

- Physical property estimations.
- Simulation of individual units like, mixers, splitters, heat exchangers, flash columns and reactors
- Design and rating of heat exchangers
- Design and rating of distillation columns.
- Mass and Energy balances.
- Handling user specifications on output streams – Sensitivity and design Spec tools.
- Simulation of a flowsheet
- Simulation exercises using calculator block

- Optimization Exercises
- Simulation using equation oriented approach
- Simulation of processes involving solids
- Costing and economic analysis using Aspen capital Cost estimation.
- Pinch analysis and design Heat exchanger networks using Aspen Energy Analyser.
- Dynamic Simulation.

CH5111	ADVANCED HEAT TRANSFER	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Derive the governing differential equation for conduction and convection heat transfer
CO2	Solve the differential equation to obtain temperature profile in solid or fluid
CO3	Apply finite difference methods to solve problems in heat transfer
CO4	Calculate the net radiation loss from a surface in an enclosure of many surfaces

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	3	-	2	-	-	-	-	-
CO2	2	-	2	-	-	-	-	-
CO3	3	-	-	-	-	-	-	-
CO4	3	-	3	-	-	-	-	-

Detailed syllabus

Steady state heat conduction: General conduction equation, side conditions. One dimensional heat conduction without generation, Plane slab, Circular cylindrical shell, Spherical shell, Variable thermal conductivity, Conduction across composite barriers, Critical insulation thickness. Finite difference methods in steady state conduction.

Unsteady state condition: Exact analytical solutions and charts for infinite slab, cylinder and sphere, Semi-infinite slab, Lumped parameter method of transient analysis; Finite difference method; Transient finite difference solutions.

Natural Convection: Governing equations for velocity and temperature fields, partial differential equations, vertical plate solution.

Forced Convection: The fundamental problem, analytical and semi-analytical solutions.

Radiation Heat transfer - Concepts, physical mechanism, properties, radiation shape factors, heat exchange between nonblack bodies, infinite parallel planes, Calculation of the net radiant loss; Net radiant loss from non-gray surfaces.

Reading:

1. Sucec J, Heat Transfer, Jaico Publishing House, 2006.
2. Holman, J.P. and White P.R.S., Heat Transfer, 7th Ed., McGraw Hill, 2009.

CH5112	RISK ANALYSIS & HAZOPS	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Identify the type of risk involved in a chemical plant operation
CO2	Manage risk and prepare disaster management options
CO3	Understand safety, energy and environmental impact audit
CO4	Implement the procedure of root cause/fault tree analysis
CO5	Conduct HAZOP study for 'to be commissioned' chemical plants

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	1	-	-	3	-	-	-	-
CO2	-	-	2	3	-	-	2	-
CO3	1	-	-	3	-	-	1	-
CO4	-	-	-	3	-	-	1	-
CO5	-	-	-	3	-	-	-	-

Detailed syllabus

Types of Risk analysis: What are Risks, threats and vulnerabilities? What are Risk assessment, Risk management and Risk communication?. Basics and structure of Risk analysis. Qualitative and quantitative risk analysis.

Types of failure: What is failure? Design failure, catastrophic failure, compounding failure and Human error failure.

Dispersion and toxic models: Parameters affecting dispersion, Neutrally buoyant dispersion models, Steady-State Continuous Point Release with No Wind, Puff with No Wind, Non-Steady-State Continuous Point Release with No Wind, Steady-State Continuous Point Source Release with Wind, Puff with No Wind and Eddy Diffusivity Is a Function of Direction, Steady-State Continuous Point Source Release with Wind and Eddy Diffusivity Is a Function of Direction, Puff with Wind, Puff with No Wind and with Source on Ground, Steady-State Plume with Source on Ground, Continuous Steady-State Source with Source at Height *Hr* above the Ground, Pasquill-Gifford Model, Puff with Instantaneous Point Source at Ground Level, Coordinates Fixed at Release Point, Constant Wind Only in x Direction with Constant Velocity *u,* Plume with Continuous Steady-State Source at Ground Level and Wind Moving in x Direction at Constant Velocity *u,* Plume with Continuous Steady-State Source at Height *Hr* above, Ground Level and Wind Moving in x Direction at Constant Velocity *u,* Puff with Instantaneous Point Source at Height *Hr* above Ground Level and a Coordinate System on the Ground That Moves with the Puff, Puff with Instantaneous Point Source at Height *Hr* above Ground Level and a Coordinate System Fixed on the Ground at the Release Point, Worst-Case Conditions, Limitations to Pasquill-Gifford Dispersion Modeling, Dense Gas Dispersion, Toxic Effect Criteria, Effect of release momentum and Buoyancy, Release Mitigation.

Fire and explosion models: The Fire Triangle, Distinction between Fires and Explosions, Flammability Characteristics of Liquids and Vapors, Liquids, Gases and Vapors, Vapor Mixtures, Flammability Limit, Dependence on Temperature, Flammability Limit Dependence on Pressure, Estimating Flammability Limits, Limiting Oxygen Concentration and Inerting, Flammability Diagram, Ignition Energy, Autoignition, Auto-Oxidation, Adiabatic Compression, Ignition Sources, Sprays and Mists, Explosions, Detonation and Deflagration, Confined Explosions, Blast Damage Resulting from Overpressure, TNT Equivalency, TNO Multi-Energy Method, Energy of Chemical Explosions, Energy of Mechanical Explosions, Missile Damage, Blast Damage to People, Vapor Cloud Explosions, Boiling-Liquid Expanding-Vapor Explosions.

Risk Management and ISO14000: Disaster management plan: Scale of disaster, elements at risk, aims of disaster management, disaster management cycle, role players in disasters, disaster preparedness, disaster preparedness framework, disaster response activities.

Emergency Planning: Internal Emergency Plan (for the employees of the company), Objectives of an internal emergency plan, The Preparation of an Emergency plan, Elements of an Emergency plan, Emergency Organization and Management. External Emergency Plan (for the surrounding communities).

Case studies: Static Electricity, Tank Car Loading Explosion, Explosion in a Centrifuge, Duct System Explosion, Conductor in a Solids Storage Bin, Pigment and Filter, Pipefitter's Helper, Lessons Learned, Chemical Reactivity, Bottle of Isopropyl Ether, Nitrobenzene Sulfonic Acid Decomposition, Organic Oxidation, Lessons Learned, System Designs, Ethylene Oxide Explosion, Ethylene Explosion, Butadiene Explosion, Light Hydrocarbon Explosion, Pump Vibration, Pump Failure, Ethylene Explosion, Ethylene Explosion, Ethylene Oxide Explosion,, Procedures, Leak Testing a Vessel, Man Working in Vessel, Vinyl Chloride Explosion, Dangerous Water Expansion, Phenol-Formaldehyde Runaway Reaction, Conditions and Secondary Reaction Cause Explosion. Fuel-Blending Tank Explosion.

Hazard identification: Process Hazards Checklists, Hazards Surveys, Hazards and Operability Studies, Safety Reviews, Other Methods.

Safety Audits: Types of audits (Internal &External), Audits objectives, Methodology in Conducting Safety audits (Pre-audit activities, Key on-sites activities and Post-audit activities).

Checklists: Process hazard checklists.

What if Analysis: Examination of possible deviations from the design, construction, modification or operating intent of a process.

Vulnerability models: Definitions of vulnerability, Characteristics of vulnerability, Types of vulnerability, Conceptual frame-works of vulnerability, Methods of Measuring physical vulnerability, Analytical Methods and Earthquake vulnerability curves.

Event tree and Fault tree Analysis: Guidelines, examples, fault tree analysis symbols, building fault tree, DOs and DONOTs in fault tree analysis, Past accident analysis, Hazops, Principles, Risk ranking, Guide word, Parameter, Deviation, Causes, Consequences, Recommendation, Coarse HAZOP study, Case studies

Reading:

1. Raghavan K. V. and Khan A. A., Methodologies in Hazard Identification and Risk Assessment, Manual by CLRI, 1990.
2. Marshal V. C., Major Chemical Hazards, Ellis Horwood Ltd., Chichester, United Kingdom, 1987.
3. Mannan S., Butterworth Heineman, Lees' Loss Prevention in the Process Industries, 4th Ed., Hazard Identification, Assessment and Control, 2012.

CH5113	STATISTICAL DESIGN OF EXPERIMENTS	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Plan experiments for a critical comparison of outputs
CO2	Include statistical approach to propose hypothesis from experimental data
CO3	Implement factorial and randomized sampling from experiments
CO4	Estimate parameters by multi-dimensional optimization

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	2	-	-	3	-	-	-	-
CO2	2	1	-	-	-	-	-	-
CO3	2	1	-	-	-	-	-	-
CO4	-	3	-	2	-	-	-	-

Detailed syllabus

Introduction: Strategy of experimentation, basic principles, guidelines for designing experiments.

Simple Comparative Experiments: Basic statistical concepts, sampling and sampling distribution, inferences about the differences in means: Hypothesis testing, Choice of samples size, Confidence intervals, Randomized and paired comparison design.

Experiments with Single Factor; An example, The analysis of variance, Analysis of the fixed effect model, Model adequacy checking, Practical interpretation of results, Sample computer output, Determining sample size, Discovering dispersion effect, The regression approach to the analysis of variance, Nonparametric methods in the analysis of variance, Problems.

Design of Experiments: Introduction, Basic principles: Randomization, Replication, Blocking, Degrees of freedom, Confounding, Design resolution, Metrology considerations for industrial designed experiments, Selection of quality characteristics for industrial experiments.

Parameter Estimation.

Response Surface Methods: Introduction, The methods of steepest ascent, Analysis of a second-order response surface, Experimental designs for fitting response surfaces: Designs for fitting the first-order model, Designs for fitting the second-order model, Blocking in response surface designs, Computer-generated (Optimal) designs, Mixture experiments, Evolutionary operation, Robust design, Problems.

Design and Analysis: Introduction, Preliminary examination of subject of research, Screening experiments: Preliminary ranking of the factors, active screening experiment-method of random balance, active screening experiment Plackett-Burman designs, Completely randomized block design, Latin squares, Graeco-Latin Square, Youdens Squares, Basic experiment-mathematical modeling, Statistical Analysis, Experimental optimization of research subject: Problem of optimization, Gradient optimization methods, Nongradient methods of optimization, Simplex sum rotatable design, Canonical analysis of the response surface, Examples of complex optimizations.

Reading:

1. Lazic Z. R., Design of Experiments in Chemical Engineering, A Practical Guide, Wiley, 2005.
2. Antony J., Design of Experiments for Engineers and Scientists, Butterworth Heinemann, 2004.
3. Montgomery D. C., Design and Analysis of Experiments, 5th Ed., Wiley, 2010.

CH5114	MULTI-PHASE FLOW	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Identify the types of multiphase flow according to liquid-liquid, solid-liquid, gas-liquid, solid-gas and solid-gas-liquid combination in a given chemical engineering operation.
CO2	Categorize the regimes of flow condition for each of the above combinations.
CO3	Estimate pressure drop requirements for conveying multi-phase fluids through closed conduits such as circular pipes.
CO4	Understand the advantages and disadvantages of multiphase flow phenomena on chemical product manufacture.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	3	-	-	-	-	-	-	-
CO2	3	2	-	2	-	-	-	-
CO3	-	2	3	-	-	-	-	-
CO4	3	-	-	2	-	-	-	-

Detailed syllabus

Introduction: gas-liquid, liquid-liquid, liquid-solid, gas-solid, solid-liquid-gas systems.

Gas-Liquid Flows: Horizontal flow, Vertical flow, momentum and energy relations, Flow patterns in horizontal tube, Flow patterns in vertical tube, Derivation of velocity profile in stratified flow between two parallel plates, Liquid hold up – correlations, Pressure drop calculation.

Bubble and drop formation: Phase holdups, Interfacial areas, mixing and pressure drops, Bubble formation, Terminal settling velocity of a gas bubble (assuming a rigid sphere), Terminal settling velocity of a gas bubble (assuming a spherical cap) – Haberman-Morton's number, Interfacial area, Mixing.

Solid-Gas Flow: Flow regimes, Suspension mechanism, determination of voids, energy requirements for pneumatic conveying, pressure drop and solid velocities in dilute phase flow, dense phase conveying, vertical transport, Flow regimes, Fluidization – Dilute & Dense.

Solid-Liquid Flows: Rheology of slurries, Sedimentation mechanism.

Gas-Liquid-Solid Flow: Classification, Operating modes, Detailed description of two operating modes.

Reading:

1. Govier, G.W. and Aziz, K., The flow of complex mixtures in pipe, Krieger Publication Florida, 2008.
2. King R. P., Introduction to Practical Fluid Flow, Butterworth-Heinmann, 2003.
3. Coulson J M and Richardson J. F, Chemical Engineering, Vol., 6^{th} Ed., Butterworth-Heinemann, Oxford, 1999.
4. Fan L. S., Gas-liquid-solid Fluidization Engineering, Butterworth Publishers, Boston, 1989.

CH5115	PROJECT EVALUATION	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Analyze alternative processes and equipment for manufacturing product
CO2	Perform economic analysis related to process and equipment design
CO3	Estimate the cost of manufacture
CO4	Evaluate project profitability

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	-	2	2	2	-	-	-	-
CO2	-	-	3	-	-	-	-	-
CO3	-	-	3	-	-	-	-	-
CO4	-	-	3	1	-	-	-	-

Detailed syllabus

Introduction to Industrial Project Management: Nature of the Industrial Project, The Industrial Project Manager, The Professional Chemical Engineer, The Economic Basis of the Industrial Project.

The Mathematics of Finance: The Measurement of Interest, The Present Worth of Cash Flows, Annuities.

Project Evaluation Systematics: Principles of Preliminary Project Evaluation, Marketing Research, Demand Projection, Price Projection, Flow Sheet Development Methods in Cost Estimation.

Equipment Design And Costing: Equipment Selection and Sizing for Preliminary Cost Estimates, Estimation of Purchased Cost of Equipment, Effect of Inflation upon Capital Costs, Cost of Equipment Installation, Reliability of Equipment Cost Estimation.

The Direct Fixed Capital Investment: The Estimation of Direct Fixed Capital, The Separate Estimation of Auxiliary Facilities, The Estimation of Piping Systems, Reliability of Capital Estimates.

Depreciation: The Economic Impact of Depreciation, Methods of Determining Depreciation Charges.

Cost of Manufacture: The Elements of the Cost of Manufacture, Raw Materials and Utilities, Operating Labor, Regulated and Fixed Charges, The Total Cost for Sale, The Responsibility for Environmental Projection.

The Criterion for Economic Performance: The Capital for Transfer, Return on Investment, Profitability under Variable Conditions, Profitability Criteria Related to ROI, The Costs of Product Transportation.

Cash Flow Analysis: Cash Flow Concepts, Net Present Worth, Discounted Cash Flow, Relative Merit of Profitability Criteria, The Analysis of Risk.

The Analysis of Alternatives: The Analysis of Equipment Alternatives, The Analysis of Process and Investment Alternatives, Economic Optimization, Replacement Analysis, Plant Modification Decisions, Engineering Management of Construction Projects, Corporate Performance Analysis, Optimum Design and Design Strategy, Statistical Analysis in Design.

Reading:

1. Valle-Riestra J. F., Project Evaluation in the chemical process Industries. McGraw Hill Book Co., 1983.
2. Peters M.S., Timmerhaus K. D. and West R. E., Plant Design and Economics for Chemical Engineers, Tata McGraw Hill., 5th Edition, 2011.

CH5116	CONCEPTUAL DESIGN OF CHEMICAL PROCESSES	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Implement the hierarchical approach to conceptual design
CO2	Optimize the input/output and recycle structure of the flowsheet
CO3	Design the best flow sheet using conceptual design
CO4	Synthesise heat exchanger network and separation systems.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	2	-	-	-	-	-	-	-
CO2	-	2	2	-	-	-	-	-
CO3	-	2	1	1	-	-	-	-
CO4	-	2	-	-	-	-	-	-

Detailed syllabus

The nature of process synthesis and analysis: Creative Aspects of process design, A Hierarchical approach to conceptual design.

Engineering economics: Cost information required, estimating capital and operating costs, total capital investment and total product costs, time value of money, Measures of process profitability, Simplifying the economic analysis for conceptual designs.

Economic decision making: Design of a solvent recovery system, Problem definition and general considerations, Design of a gas absorber, Equipment design considerations, rules of thumb.

Developing a conceptual design and finding the best flow sheet: Input information, batch versus continuous.

Input-output structure of the flowsheet: Decisions for the input-output structure, Design variables, Overall material balances, and stream costs, Process Alternatives.

Recycle structure of the flowhseet: Decisions that determine the recycle structure, recycle material balances reactor heat effects, equilibrium limitations, compressor design and costs reactor design, recycle economic evaluation.

Separation system: General structure of the separation system, Vapor recovery system, Liquid separation system, Azeotropic systems, Rigorous material balances.

Heat-exchanger networks: Minimum heating and cooling requirements, Minimum number of exchangers, Area estimates, Design of minimum-energy heat exchanger networks, Loops and paths, Reducing the number of exchangers, Stream splitting, Heat and Power integration, Heat and distillation, HDA Process.

Cost diagrams and quick screening of process alternatives: Cost diagrams, cost diagrams for complex processes, quick screening of process alternatives, HDA Process.

Reading:

1. Douglas J. M., Conceptual Design of Chemical Processes, McGraw Hill, 1988.
2. Dimian A. C., Bidea C. S., Chemical Process Design, Wiley-VCH, 2008.

CH5161	MEMBRANE SEPARATION TECHNIQUES	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Classify the membranes.
CO2	Differentiate various membrane processes.
CO3	Understand the methods of membrane preparation.
CO4	Select a membrane and membrane process.
CO5	Evaluate the flux of solvent and solute through membrane.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	3	-	-	-	-	-	-	-
CO2	3	-	-	-	-	-	-	-
CO3	-	-	2	-	-	-	-	-
CO4	-	-	2	-	-	-	-	-
CO5	-	-	-	3	-	-	-	-

Detailed syllabus

Introduction: Membrane separation process, Definition of Membrane, Membrane types, Advantages and limitations of membrane technology compared to other separation processes, Membrane materials and properties.

Preparation of synthetic membranes: Phase inversion membranes, Preparation techniques for immersion precipitation, Synthesis of asymmetric and composite membranes and Synthesis of inorganic membranes.

Transport in membranes: Introduction, Driving forces, Non-equilibrium thermodynamics, Transport through porous membranes, transport through non-porous membranes, Transport through ion-exchange membranes.

Membrane processes: Pressure driven membrane processes, Concentration as driving force, Electrically driven membrane processes

Polarisation phenomena and fouling: Concentration polarization, Pressure drop, Membrane fouling, methods to reduce fouling.

Modules: Introduction, membrane modules, Comparison of the module configurations

Reading:

1. Mulder M, *Basic Principles of Membrane Technology*, Kluwer Academic Publishers, London, 1996.
2. Baker R. W., Membrane Technology and Research, Inc.(MTR), Newark, California, USA, 2004.
3. Nath K., Membrane Separation Processes, Prentice-Hall Publications, New Delhi, 2008.

CH5162	ADVANCED MASS TRANSFER	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand the concept of separation factor and separating agent.
CO2	Determine the degrees of freedom using phase rule and description rule.
CO3	Compare multi-stage operations.
CO4	Design binary distillation column using McCabe Thiele and Ponchon-Savarit methods.
CO5	Design multi-component distillation columns using short cut and rigorous calculation methods.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	2	-	-	-	-	-	-	-
CO2	-	3	-	-	-	-	-	-
CO3	2	-	-	-	-	-	-	-
CO4	3	2	-	-	-	-	-	-
CO5	3	2	-	-	-	-	-	-

Detailed syllabus

Characterization of Separation processes: Inherent Separation Factors: Equilibration Processes, Inherent Separation Factors: Rate-governed Processes.

Simple equilibrium processes: Equilibrium Calculations, Checking Phase Conditions for a Mixture.

Multistage separation processes: Increasing Product Purity, Reducing Consumption of Separating Agent, Cocurrent, Crosscurrent, and Countercurrent Flow.

Binary multistage separation: Binary Systems, Equilibrium Stages, McCabe-Thiele Diagram, The Design Problem, Multistage Batch Distillation, Choice of Column Pressure.

Binary multistage separations-general graphical approach: Straight Operating Lines, Curved Operating Lines Processes without Discrete Stages, General Properties of the yx Diagram.

Energy requirements of a separation process: Minimum Work of Separation, Net Work Consumption, Thermodynamic Efficiency, network of potentially reversible process, partially reversible process and irreversible processes.

Multi-component: Equilibrium and simple distillation – Multi-component Flash calculation and Differential distillation, quantitative relationships.

Ternary and multi-component system fractionation: preliminary calculations, feed condition, column pressure, design procedure, number of equilibrium stages, feed location, estimation of number of theoretical plates – shortcut methods and rigorous calculation methods.

Reading:

1. King C. J., Separation Processes, Tata McGraw Hill Book Company, 2nd Ed., New Delhi, 1983.
2. Vanwinkle M, Distillation, McGraw Hill Chemical Engineering Series, New York, 1967.
3. Holland C. D., Multi-component Distillation, Prentice Hall of India Pvt. Ltd., 1981.
4. Geankoplis C. J., Transport Processes and Unit Operations, 4thEdition, Prentice Hall of India Pvt. Ltd., New Delhi, 2004.

CH5163	ENERGY MANAGEMENT	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Implement energy audit for a chemical plant
CO2	Suggest methods of conserving energy requirement
CO3	Evaluate the suitability of renewable energy resources
CO4	Analyze the energy utilization of a process equipment

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	-	-	3	-	-	-	-	-
CO2	-	-	3	-	-	-	-	-
CO3	-	-	3	-	-	-	-	-
CO4	-	-	3	-	-	-	-	-

Detailed syllabus

Energy Scenario: Energy use patterns, energy resources, Oil a critical resource, economic and environmental consideration, Future scenario

Heat & work: First & second law of thermodynamics, Heat Engines.

Energy Audit: Energy conversion, Energy index, Energy consumption representation - pie chart, Sankey diagram & load profile, general audit, detailed audit, waste heat recovery.

Targeting and Conservation: Energy utilization and conversion – thermal efficiency, Heat Exchangers – heat recovery , Air conditioners – supply and removal of heat.

Recent advances in energy: Solar energy, Wind energy, Nuclear energy, Biomass, Geothermal energy, Future Energy Alternatives.

Case Studies: Energy conservation in alcohol industry, fertilizer industry, and pulp and paper industry, Energy conservation in different units of refinery like FCCU, HCU and ADU.

Reading:

1. Murphy W.R. and Mckay G., Energy Management, Elsevier, 2007.
2. HinrichsR. A. and Kleinbach M. H., Energy: Its Use and the Environment, Cengage Learning, 2012.

3. Capehart B. L., Turner W. C. and Kennedy W. J., Guide to Energy Management, 7 th Ed., KeinneduFairmant press (2011).
4. Rai G. D., Non-conventional Energy Sources, Khanna Publishers, New Delhi, 2010.

CH5164	PINCH TECHNOLOGY	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Quantify the energy requirement for component equipment of a chemical plant
CO2	Develop the composite curves and locate the pinch point for heat exchanger network
CO3	Minimize energy requirement for the heat exchanger network
CO4	Implement pinch technique for batch and continuous processes
CO5	Optimize energy requirement for a large chemical plant by compartmentalizing appropriately

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	3	-	3	-	-	-	-	-
CO2	2	2	3	1	-	-	-	-
CO3	2	2	3	-	-	-	-	-
CO4	-	-	3	1	-	-	-	-
CO5	-	-	-	-	-	-	-	-

Detailed syllabus

Introduction: Pinch analysis, History, Concepts of process synthesis, Learning & applying techniques.

Key concepts of Pinch analysis: Heat recovery & heat exchange, Significance, Heat Exchanger network design, Implications, Methodology.

Data extraction and energy targeting: Data extraction, Case study – organics distillation plant, Energy Targeting, Multiple utilities, Advance energy targeting, Targeting heat exchange units, area and shells, Super targeting – Cost targeting for optimal difference in temperature, case study – organic distillation plant.

HEN Design Utilities: Introduction, Heat Exchanger equipment, Stream splitting and cyclic matching, Network relaxation, complex design, multiple pinches and near pinches, retrofit design, operability, network design for organics distillation – case study.

Heat and power systems: Introduction, CHP systems, Heat pump & refrigeration system, total site analysis, organic distillation unit, case studies.

Process change and evolution: Introduction, principles, reactor systems, distillation column, separation systems, applications to the organic distillation.

Batch and time dependent processes: Introduction, streams in batch processes, time intervals, calculating energy targets, heat exchanger network design, rescheduling, debottlenecking, time dependent applications.

Applying the Technology in Practice: Introduction, Pinch study, heat & mass balance, Stream data extraction, targeting & network design, Targeting softwares, industrial experience.

Case Studies: Introduction, crude preheat train, aromatics plant, Evaporation plants, organic chemicals manufacturing site.

Reading:

1. Kemp I. C., Pinch Analysis and Process Integration, 2nd Ed., 2007, Elsevier Publication.
2. Noureddin M. B., Pinch Technology and Beyond Pinch, New Vistas on Energy Efficiency Optimization, Booktopia 2011.
3. Biegler L. T., Grossmann I. E. and Westerberg A. W., Systematic Methods of Chemical Process Design, Prentice Hall, 1997.

CH5165	REACTIVE SEPARATIONS	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand the need for reactive separation process
CO2	Categorize reactive separation processes.
CO3	Understand the effect of thermodynamics and kinetics on the reactive separation process
CO4	Develop mass and energy balance equations for reactive separation processes

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	2	2	3	-	-	-	-	-
CO2	3	2	3	-	-	-	-	-
CO3	3	3	-	-	-	-	-	-
CO4	3	-	-	-	-	-	-	-

Detailed syllabus

Reactive Distillation: Definition, introduction to reactive distillation process.

Thermodynamic and kinetic effects on the feasible products of RD: introduction, Azeotropes, arheotropes, kinetics arheotropes in reactive membrane separation, Equilibrium theory and nonlinear waves for reaction separation process.

Reactive stripping in structured catalytic reactors: introduction, hydrodynamics, Reactive experiments, comparison of different internals.

Reactive Absorption: introduction, reactive absorption equipment, modeling concept, model parameters, case studies.

Reactive Extraction: introductions, phase equilibria, reactive mass transfer, hydrodynamics.

Development of reactive crystallization process: introduction, work flow in process development, process synthesis, reactive phase diagrams, kinetic effects, asymmetric transformation of enantiomers.

Reactive extrusion for solvent free processing: introduction, advantages & disadvantages, main reactions in extruders, extruder types, kinetic considerations, heat transfer and thermal instabilities.

Reactive comminution: introduction, mechanical comminution in solids, equipment and processes, applications.

Reactive filtration: introduction, separation of particulates and catalytic reaction of volatiles, separation of particles and reaction of solids.

Reactive assisted granulation in fluidized beds: introduction, modeling, experiments.

Reading:

1. Sundmacher K., Kienle A., Siedel A., Integrated Chemical Processes, Wiley VCH, 2005.
2. Kulprathipanja, Reactive Separation Processes, Taylor and Francis, 2002.
3. LuybenW. L. and Cheng-Ching Yu, Reactive Distillation Design and Control, John Wiley and Sons, 2008.

CH5166	PROCESS INTENSIFICATION	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Apply process intensification in industrial processes.
CO2	Implement methodologies for process intensification
CO3	Understand scale up issues in the chemical process.
CO4	Gain the scientific background, techniques and applications of intensification in the process industries.
CO5	Identify and solve process challenges using intensification technologies.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	2	-	-	-	-	-	-	-
CO2	-	2	1	-	-	-	-	-
CO3	3	2	-	-	-	-	-	-
CO4	2	1	2	-	-	-	-	-
CO5	2	2	3	1	-	-	-	-

Detailed syllabus

Introduction: Techniques of Process Intensification (PI) Applications, The philosophy and opportunities of Process Intensification, Main benefits from process intensification, Process-Intensifying Equipment, Process intensification toolbox, Techniques for PI application.

Process Intensification through micro reaction technology: Effect of miniaturization on unit operations and reactions, Implementation of Microreaction Technology, From basic Properties To Technical Design Rules, Inherent Process Restrictions in Miniaturized Devices and Their Potential Solutions, Microfabrication of Reaction and unit operation Devices - Wet and Dry Etching Processes.

Scales of mixing, Flow patterns in reactors, Mixing in stirred tanks: Scale up of mixing, Heat transfer. Mixing in intensified equipment, Chemical Processing in High-Gravity Fields Atomizer Ultrasound Atomization, Nebulizers, High intensity inline MIXERS reactors Static mixers, Ejectors, Tee mixers, Impinging jets, Rotor stator mixers, Design Principles of static Mixers Applications of static mixers, Higee reactors.

Combined chemical reactor heat exchangers and reactor separators: Principles of operation; Applications, Reactive absorption, Reactive distillation, Applications of RD Processes, Fundamentals of Process Modelling, Reactive Extraction Case Studies: Absorption of NOx Coke Gas Purification.

Compact heat exchangers: Classification of compact heat exchangers, Plate heat exchangers, Spiral heat exchangers, Flow pattern, Heat transfer and pressure drop, Flat tube-and-fin heat exchangers, Microchannel heat exchangers, Phase-change heat transfer, Selection of heat exchanger technology, Feed/effluent heat exchangers, Integrated heat exchangers in separation processes, Design of compact heat exchanger - example.

Enhanced fields: Energy based intensifications, Sono-chemistry, Basics of cavitation, Cavitation Reactors, Flow over a rotating surface, Hydrodynamic cavitation applications, Cavitation reactor design, Nusselt-flow model and mass transfer, The Rotating Electrolytic Cell, Microwaves, Electrostatic fields, Sonocrystallization, Reactive separations, Superctrical fluids.

Reading:

1. Stankiewicz, A. and Moulijn, (Eds.), Reengineering the Chemical Process Plants, Process Intensification, Marcel Dekker, 2003.
2. Reay D., Ramshaw C., Harvey A., Process Intensification, Butterworth Heinemann, 2008.

CH5167	PROCESS INTEGRATION	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand process integration and its need in a chemical plant
CO2	Apply mass integration strategies
CO3	Apply heat integration strategies
CO4	Apply mathematical techniques for synthesis of mass and heat integration networks

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	3	-	2	1	-	-	-	-
CO2	2	2	2	-	-	-	-	-
CO3	2	2	2	-	-	-	-	-
CO4	3	3	3	-	-	-	-	-

Detailed syllabus

Introduction to Process Integration: Generating Alternatives for Debottlenecking and Water Reduction in Acrylonitrile Process, Traditional Approaches to Process Development and Improvement, What is Process Synthesis?, What is Process Analysis?, Why Integration?, What is Process Integration?, Categories of Process Integration.

Overall Mass Targeting: Targeting for Minimum Discharge of Waste, Targeting for Minimum Purchase of Fresh Material Utilities, Mass-Integration Strategies for Attaining Targets.

Graphical Techniques for Direct-Recycle: Strategies, Problem Statement, Source–Sink Mapping Diagram and Lever-Arm Rules, Selection of Sources, Sinks, and Recycle Routes, Direct-Recycle Targets Through Material Recycle Pinch Diagram, Design Rules from the Material Recycle Pinch Diagram, Multicomponent Source–Sink Mapping Diagram

Synthesis of Mass Exchange Networks: A Graphical Approach, Design of Individual Mass Exchangers, Cost Optimization of Mass Exchangers, Problem Statement for Synthesis of Mass Exchange Networks, Mass Exchange Pinch Diagram, Screening of Multiple External MSAs and Constructing the Pinch Diagram without Process Mass, Example – Wastewater Treatment.

Visualization Techniques for the Development of Detailed Mass-Integration Strategies: Low/No Cost Strategies, Modest Changes in Process Variables and Operating Conditions, Medium-Cost Strategies and Main Technology Changes.

Algebraic Approach to Targeting Direct Recycle: Problem Statement, Algebraic Targeting Approach, Algebraic Targeting Procedure, Case Study: Targeting for Acetic Acid Usage in a Vinyl Acetate Plant.

An Algebraic Approach to the Targeting of Mass Exchange Networks: The Composition-Interval Diagram, Table of Exchangeable Loads, Mass Exchange Cascade Diagram, Example on Cleaning of Aqueous Wastes.

Recycle Strategies Using Property Integration: Property-Based Material Recycle Pinch Diagram, Process Modification Based on Property-Based Pinch Diagram, Example on Solvent Recycle in Metal Degreasing, Clustering Techniques for Multiple Properties, Cluster-Based Source–Sink Mapping Diagram for Property-Based Recycle and Interception, Property-Based Design Rules for Recycle and Interception, Dealing with Multiplicity of Cluster-to-Property Mapping, Papermaking and Fiber Recycle Example, Relationship between Clusters and Mass Fractions.

Heat Integration: Synthesis of Heat Exchange Networks (HENs), Heat Exchange Pinch Diagram, Minimum Utility Targeting Through an Algebraic Procedure, Case Studies.

Combined Heat and Power Integration: Heat Engines, Heat Pumps, Heat Engines and Thermal Pinch Diagram, Heat Pumps and Thermal Pinch Diagram, Cogeneration Targeting, Additional Readings.

Mathematical Approach to Direct Recycle: Problem Statement, Problem Representation, Optimization Formulation, Interaction between Direct Recycle and the Process.

Mathematical Techniques for the Synthesis of Mass and Heat Exchange Networks: Synthesis of HENs, Synthesis of MENs.

Mathematical Techniques for Mass Integration: Source-Interception–Sink Representation, Incorporation of Process Model in Mass Integration.

Reading:

1. El-Halwagi M. M., Process Integration, 1st Edition, Academic Press, 2006.
2. Smith R., Chemical Process: Design and Integration, 1st Edition, Wiley, 2005.

CH5168	STRATEGY OF PROCESS ENGINEERING	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Integrate economic consideration with process conditions for optimization
CO2	Implement sub-optimization and cyclic methods
CO3	Plan and accommodate room for future development in a chemical plant design
CO4	Understand uncertainty in data and provide contingency for fault tolerance.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	-	2	3	-	-	-	-	-
CO2	2	-	2	-	-	-	-	-
CO3	-	2	3	1	-	-	-	-
CO4	-	-	-	2	-	-	-	-

Detailed syllabus

System and subsystem in chemical process engineering: System analysis, Process synthesis, Process The synthesis of plausible alternatives, the structure of systems,

Economic design criteria : Economic degree of freedom , The search for optimum conditions, The sub-optimization of systems with acyclic structure, Macro system optimization strategies, Capital cost and manufacturing cost estimation methods, Terms involved in profitability analysis.

Strategy of scale-up and design of chemical processes: Role of pilot plant, process validation, salient features of patent literature.

Preparation of process specifications for typical equipment: Choice of batch v/s continuous process, Time cycle for batch processes, Concept of dedicated and multiproduct plant facilities, Development and evaluation of alternative flow sheets, Preparation of process and instrumentation diagrams.

Efficient utilization of energy: Heat exchanger net-works.

Process evaluation: Selection with special reference to eco-friendly technologies, Conceptual project implementation - stage wise, Accommodating to future developments, Accounting for uncertainty in data, Failure tolerance.

Reading:

1. Rudd D. F. and Watson C. C., Strategy of Process Engineering, John Wiley, 1968.
2. Douglas J. M., Conceptual Design of Chemical Processes, McGraw Hill, 1988.

CH5169	BIOPROCESS ENGINEERING	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand enzyme kinetics and cell kinetics.
CO2	List the immobilization techniques.
CO3	Calculate the time required for a given conversion of a enzymatic reactions using the kinetic data.
CO4	Select downstream processing method for purification of the product.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	2	3	-	2	-	-	-	-
CO2	3	2	-	-	-	-	-	-
CO3	3	2	-	1	-	-	-	-
CO4	2	-	3	-	-	-	-	-

Detailed syllabus

Introduction: Biotechnology, Biochemical Engineering, Biological Process, Definition of Fermentation.

Enzyme & Cell Kinetics: Introduction, Simple Enzyme Kinetics, Enzyme Reactor with Simple Kinetics, Inhibition of Enzyme Reactions, Other influences on Enzyme Reactions, Experiment: Enzyme Kinetics, Growth Cycle for Batch Cultivation.

Transport Phenomena in Bioprocess Systems, Bioreactor Design and Analysis.

Instrumentation and Control: Introduction, Instrumentation for Measurements of Active Fermentation, Sterilization.

Product Recovery Operations: Strategies to Recover and Purify Products, Separation of Insoluble Products, Cell Disruption, Separation of Soluble Products, Finishing Steps for Purification, Integration of Reaction and Separation.

Reading:

1. Veith W. R., Bioprocess Engineering, John Wiley & Sons, 1994.
2. Blanch H. W. and Clark D. S., Biochemical Engineering, Marcell and Dekker Inc., 1997.
3. Shuler M. L., Kargi F., Bioprocess Engineering: Basic Concepts,2nd Edition, Prentice Hall International, 2001.

CH5141	SEMINAR	PCC	0– 0 – 2	1 Credit

Pre-requisites: None

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

CO1	Communicate with group of people on different topics
CO2	Prepare a seminar report that includes consolidated information on a topic

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	-	-	-	-	3	-	-	-
CO2	-	-	-	-	-	2	2	3

Detailed syllabus

Any topic of relevance to chemical and allied engineering and science.

CH5191	SEMINAR	PCC	0– 0 – 2	1 Credits

Pre-requisites: None

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

CO1	Communicate with group of people on different topics
CO2	Prepare a seminar report that includes consolidated information on a topic

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	-	-	-	-	3	-	-	-
CO2	-	-	-	-	-	2	2	3

Detailed syllabus

Any topic of relevance to chemical and allied engineering and science.

CH6142	COMPREHENSIVE VIVA-VOCE	PCC	0 – 0 – 0	4 Credits

Pre-requisites: None

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

CO1	Demonstrate an understanding of advanced topics.
CO2	Explain the principles, phenomena and their applications.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	3	2	1	1	2	1	-	2
CO2	3	2	2	1	3	2	-	2

Detailed syllabus

Chemical Engineering courses of I year.

CH6149	DISSERTATION PART-A		0 – 0 – 0	8 Credits

Pre-requisites: None

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

CO1	Identify the problem based on literature survey
CO2	Formulate the problem
CO3	Identify the methods or techniques required for the solution
CO4	Develop the solution methodology

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	-	-	-	-	2	2	3	3
CO2	3	-	-	-	2	3	3	-
CO3	2	3	-	-	2	-	-	-
CO4	2	3	-	-	2	3	3	3

CH6199	DISSERTATION PART-B		0 – 0 – 0	18 Credits

Pre-requisites: CH6149 Dissertation Part-A

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

CO1	Implement the methods/techniques identified in dissertation part-A
CO2	Analyze and interpret the results obtained
CO3	Compare the results obtained with literature.
CO4	Demonstrate the original contribution to knowledge

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	-	3	-	-	2	3	3	-
CO2	2	2	-	-	2	3	3	-
CO3	1	1	-	-	2	3	3	3
CO4	2	2	1	2	2	3	3	3