NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

SCHEME OF INSTRUCTION AND SYLLABI

FOR

M.TECH PROGRAM IN CHEMICAL ENGINEERING

Effective from 2019-20

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 undergraduate and graduate 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.

DEPARTMENT OF CHEMICAL ENGINEERING

M.TECH IN CHEMICAL ENGINEERING

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 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

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

PO1	Independently carry out research /investigation and development work to solve practical problems.	
PO2	Write and present a substantial technical report/document.	
PO3	Model chemical engineering processes including multi-component mass transfer, multi-phase momentum transfer and multi-mode heat transfer from advanced engineering perspective.	
PO4	Apply modern experimental, computational and simulation tools to minimize the cost & energy by taking care of environment health and safety in Chemical and allied engineering industries.	
PO5	Contribute effectively in a team and demonstrate leadership skills with professional ethics.	
PO6	Pursue life-long learning, updating knowledge and skills for professional and societal development.	

Mapping of program outcomes with program educational objectives

Programn outcome	PEO1	PEO2	PEO3	PEO4	PEO5
PO1	3	3	2	1	2
PO2	2	2	2	2	3
PO3	3	3	3	2	2
PO4	2	2	3	2	2
PO5	2	2	2	2	3
PO6	2	2	1	2	3

CURRICULAR COMPONENTS

The total course package M.Tech. Degree program will typically consist of the following components.

a) Core Courses ≥ 24 Credits
b) Elective Courses ≥ 15 Credits
c) Dissertation = 27 Credits

Degree Requirements for M. Tech in Chemical Engineering

Category of Courses	Credits Offered	Min. credits to be earned
Program Core Courses (PCC)	30	30
Departmental Elective Courses (DEC)	18	18
Dissertation	27	27
Total	75	75

SCHEME OF INSTRUCTION

M.Tech. (Chemical Engineering) Course Structure

M. Tech. I - Year I - Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat.Code
1	CH5101	Advanced Transport Phenomena	3	0	0	3	PCC
2	CH5102	Advanced Reaction Engineering	3	0	0	3	PCC
3	CH5103	Computational Techniques	3	0	0	3	PCC
4		Elective – I	3	0	0	3	DEC
5		Elective – II	3	0	0	3	DEC
6		Elective – III	3	0	0	3	DEC
7	CH5104	Computational Lab	0	1	2	2	PCC
8	CH5105	Chemical Engineering Research Lab	0	1	2	2	PCC
9	CH5141	Seminar	0	0	2	1	PCC
		TOTAL	**18**	**2**	**6**	**23**	

M. Tech. I - Year II - Semester

S. No.	Course Code	Course Title	L	T	P	Credits	Cat.Code
1	CH5251	Advanced Process Control	3	0	0	3	PCC
2	CH5151	Advanced Mass Transfer	3	0	0	3	PCC
3	CH5152	Steady State Process Simulation	3	0	0	3	PCC
4		Elective – IV	3	0	0	3	DEC
5		Elective – V	3	0	0	3	DEC
6		Elective – VI	3	0	0	3	DEC
7	CH5153	Process Synthesis and Simulation Lab	0	1	2	2	PCC
8	CH5154	Flow Modeling & Simulation Lab	0	1	2	2	PCC
9	CH5191	Seminar	0	0	2	1	PCC
		TOTAL	**18**	**2**	**6**	**23**	

M. Tech. II - Year I - Semester

S. No.	Course Code	Course Title	Credits	Cat.Code
		Industrial Training (8-10 Weeks) – Optional		
1	CH6142	Comprehensive Viva-voce	2	PCC
2	CH6149	Dissertation Part-A	9	
		TOTAL	**11**	

M. Tech. II - Year II - Semester

S. No.	Course Code	Course Title	Credits	Cat.Code
1	CH6199	Dissertation Part-B	18	
		TOTAL	**18**	

List of Electives

I Year I Semester

S.No	Course Code	Course Title
1.	CH5111	Process Modeling and Analysis
2.	CH5112	CO_2 Capture and Utilization
3.	CH5113	Safety analysis in Process Industries
4.	CH5114	Statistical Design of Experiments
5.	CH5115	Chemical Process Synthesis
6.	CH5116	Environmental Engineering
7.	CH5117	Nuclear Power Technology
8.	CH5118	Bioprocess Engineering
9.	CH5119	Piping Engineering
10.	CH5120	Thermoset Polymer Composites
11.	CH5211	Industrial Instrumentation
12.	CH5212	Optimization Techniques
13.	CH5215	Internet for measurement and control

I Year II Semester

S.No.	Course Code	Course Title
1.	CH5161	Data Analytics
2.	CH5162	Process Scheduling & Utility Integration
3.	CH5163	Membrane Separation Techniques
4.	CH5164	Molecular Thermodynamics
5.	CH5165	Computational Fluid Dynamics
6.	CH5166	Process Intensification
7.	CH5167	Electrochemical Engineering
8.	CH5168	Industrial Wastewater Treatment
9.	CH5169	Energy Audit and Conservation

10.	CH5170	Petroleum Refining
11.	CH5261	Nonlinear Dynamics& Control
12.	CH5262	Soft Computing Techniques
13.	CH5263	Distillation Control

Note: In addition to the above listed electives, a student can also register one elective per semester from other departments and two electives per semester from other specializations of the same department, based on suitability of timetable.

DETAILED SYLLABUS

CH5101	ADVANCED TRANSPORT PHENOMENA	PCC	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 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.
CO5	Develop analogies among momentum, energy and mass transport.

Mapping of course outcomes with program outcomes

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

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.

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, 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. 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.
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. Mauri Robert., Transport Phenomena in Multiphase Flows, Springer International Publishing, Switzerland, 2015.
4. Koichi Asano, Mass Transfer: From Fundamentals to Modern Industrial Applications, Wiley-VCH Verlag Gmbh & Co, KGaA, Weinheim, Germany, 2006.
5. Thomson W. J., Transport Phenomena, Pearson education, Asia, 2001.

CH5102	ADVANCED REACTION ENGINEERING	PCC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Evaluate heterogeneous reactor performance considering mass transfer limitations
CO2	Perform the energy balance and obtain concentration profiles in multiphase reactors.
CO3	Estimate the performance of multiphase reactors under non-isothermal conditions.
CO4	Understand modern reactor technologies for mitigation of global warming

Mapping of course outcomes with program outcomes

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

Detailed syllabus

Non-Isothermal reaction modeling in CSTR &Batch Semi-Batch reactor: Energy Balance equations for CSTR, PFR and Batch reactors. Unsteady state non isothermal reactor design, adiabatic operation in batch, Heat effects in semi-batch. Auto-thermal Plug flow reactors and packed tubular reactors.PFR with inter-stage cooling.

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: 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.CVD ,Plasma,Ultrasound reactors.

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, different techniques of mitigation of CO_2, Recent advancements, automotive monolith catalytic converter example, removal and utilization of CO_2 for thermal power plants.

Reading:

1. FoglerH.S., Elements of Chemical Reaction Engineering, Prentice Hall of India, 2008.
2. Levenspiel O., Chemical Reaction Engineering, Third Edition, John Wiley & Sons, 1999.
3. Fromment G.F. and Bischoff K.B., Chemical Reactor Analysis and Design, John Wiley, 2010.
4. Schmidt L. D, The Engineering of Chemical Reactions, Oxford, 2007.
5. Harriott P., Chemical Reactor Design, CRC Press, 2002
6. James J. Carberry.Chemical and catalytic reaction engineering 2001 Dover Pulbications

CH5103	COMPUTATIONAL TECHNIQUES	PCC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Apply linear algebra to solve engineering problems
CO2	Solve ordinary differential equations (ODEs) and partial differential equations (PDEs)
CO3	Analyze engineering problems using graph theory
CO4	Apply Statistical techniques to solve engineering problems

Mapping of course outcomes with program outcomes

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

Detailed syllabus

Linear Algebra: Linear spaces, Vector spaces, Function spaces, Linear operator theory, self-adjoint operators, Eigenvalues and eigenvectors-eigenfunctions, Cayley-Hamilton theorem, Polynomials and functions defined on matrices, Similarity transformations, Jordan forms, quadratic forms, Strum-Liouville equations and solution of boundary value problems, Finite difference equations, Difference operators.

Linear Ordinary Differential Equations Solution Methods. Nonlinear Ordinary Differential Equations: Autonomous/ non-autonomous systems of odes, Phase plane analysis, Limit cycle and bifurcation, regular and singular perturbation techniques, Chaos, Differential-Algebraic equations.

Partial Differential Equations: Partial differential operators, First order partial differential equations, Method of characteristics, Classification of the second order partial differential equations and boundary conditions, Method of separation of variables, Similarity solutions, Greens functions, Laplace and Fourier transforms.

Graph theory: Classification of graphs, matrix representation of graphs, Analysis of trees, directed graphs and networks.

Statistical methods: Random variables, Probability distributions, Stochastic Processes, Random numbers and their generation, Monte-Carlo simulation, Response surface methodology, First and second order orthogonal factorial design, Regression analysis, Least square estimation of regression parameters.

Case studies in chemical engineering

Reading:

1. Gilbert Strang, Introduction to Applied Mathematics, Wellesley Cambridge Press. 2009.

2. Gilbert Strang, Linear Algebra and Its Applications, 4th Edition, Wellesley Cambridge Press, 2009.
3. Gourdin, A. and M Boumhrat; Applied Numerical Methods. Prentice Hall India, 2000.
4. Gupta, S. K.; Numerical Methods for Engineers. New Age International, 3rd Edition, 2015.
5. Singiresu S. Rao, “Applied Numerical Methods for Engineers and Scientists” Prentice Hall, 2001.
6. Peihua Qiu, Introduction to Statistical Process Control, CRC Press, 2014.
7. Yuri A.W. Shardt, Statistics for Chemical and Process Engineers, Springer, 2015.

CH5111	**PROCESS MODELING & ANALYSIS**	**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 model building techniques
CO2	Develop first principles, grey box and empirical models for systems.
CO3	Develop mathematical models for engineering processes
CO4	Model discrete time systems

Mapping of course outcomes with program outcomes

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	1	3	1	1	1
CO2	2	1	3	1	1	1
CO3	2	1	3	1	1	1
CO4	2	1	3	1	1	1

Detailed syllabus

Introduction to modeling, a systematic approach to model building, classification of models.

Development of steady state and dynamic lumped and distributed parameter models based on conservation principles. The transport phenomena models: Momentum, energy and mass transport models. Analysis of ill-conditioned systems.

Classification of systems, system's abstraction and modeling, types of systems and examples, system variables, input-output system description, system response, analysis of system behavior, linear system, superposition principle, linearization, non-linear system analysis, system performance and performance targets.

Development of grey box models. Empirical model building. Statistical model calibration and validation. Population balance models. Examples.

Mathematical model development for different chemical engineering processes – distillation columns, reactors, heat exchangers.

Reading:

1. Ashok Kumar Verma, Process Modeling and Simulation in Chemical, Biochemical and Environmental Engineering, CRC Press, 2014.
2.
3. Amiya K. Jana, Chemical Process Modeling and Computer Simulation, 2nd Edition, Prentice Hall, 2011.
4. Jim Caldwell, Douglas K. S. Ng, Mathematical Modeling: Case Studies, Kluwer Academic Publishers, 2004.
5. Said S. E. H. Elnashaie, Parag Garhyan, Conservation Equations and Modeling of Chemical and Biochemical Processes, Marcel Dekker Publishers, 2003.
6. K. M. Hangos and I. T. Cameron, “Process Modelling and Model Analysis”, Academic Press, 2001.
7. John Ingham, Irving J. Dunn, Elmar Heinzle, J. E. Prenosil, Jonathan B. Snape, Chemical Engineering Dynamics, Wiley, 2007.
8. William L. Luyben, Process Modeling, Simulation and control for Chemical Engineers, Second Edition, McGraw-Hill Publishing Company, 1996.

CH5112	**CO2 CAPTURE AND UTILIZATION**	**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 necessity of CO_2 capture, storage and utilization
CO2	Distinguish the CO_2capture techniques
CO3	Evaluate CO_2 Storage and sequestration methods
CO4	Assess Environmental impact of CO_2 capture and utilization

Mapping of course outcomes with program outcomes

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

Detailed syllabus

Introduction: Global status of CO_2 emission trends, Policy and Regulatory interventions in abatement of carbon footprint, carbon capture, storage and utilization (CCS&U).
CO_2 capture technologies from power plants: Post-combustion capture, Pre-combustion capture, Oxy-fuel combustion, chemical looping combustion, calcium looping combustion.
CO_2 capture agents and processes: Capture processes, CO_2 capture agents, adsorption, ionic liquids, metal organic frameworks.
CO_2 storage and sequestration: Geological sequestration methods, Biomimetic carbon sequestration.
CO_2 Utilization: CO_2 derived fuels for energy storage, polymers from CO_2, CO_2 based solvents, CO_2 to oxygenated organics, Conversion into higher carbon fuels, High temperature catalysis
Environmental assessment of CO_2 capture and utilization: Need for assessment, Green chemistry and environmental assessment tools, Life cycle assessment (LCA), ISO standardization of LCA, Method of conducting an LCA for CO_2 capture and Utilization.

Reading:

1. Peter Styring, Elsje Alessandra Quadrelli, Katy Armstrong, Carbon dioxide utilization: Closing the Carbon Cycle, Elsevier, 2015.
2. Goel M, Sudhakar M, Shahi RV, Carbon Capture, Storage and, Utilization: A Possible Climate Change Solution for Energy Industry, TERI, Energy and Resources Institute, 2015.
3. Amitava Bandyopadhyay, Carbon Capture and Storage, CO_2 Management Technologies, CRC Press, 2014.

4. Fennell P, Anthony B, Calcium and Chemical Looping Technology for Power Generation and Carbon Dioxide (CO2) Capture, Woodhead Publishing Series in Energy: No. 82, 2015.
5. Mercedes Maroto-Valer M, Developments in Innovation in Carbon Dioxide Capture and Storage Technology: Carbon Dioxide Storage and Utilization, Vol 2, Woodhead Publishing Series in Energy, 2014.

CH5113	Safety Analysis in Process Industries	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 and control the fire and explosion hazards
CO2	Implement the hazard identification techniques to commission the process plant
CO3	Control the reactive chemical hazards
CO4	Understand the safety aspects in process industries

Mapping of course outcomes with program outcomes

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

Detailed syllabus
Introduction: Basic laboratory safety and personal protective equipment, Engineering ethics, Accident and loss statistics, the nature of the accident Process, Review of industrial accidents
Fire and explosion models: The Fire Triangle, Distinction between Fires and Explosions, Flammability Characteristics of Liquids and Vapours, Liquids, Gases and Vapours, Vapour Mixtures, Flammability Limit, Dependence on Temperature, Flammability Limit Dependence on Pressure, Estimating Flammability Limits, Limiting Oxygen Concentration and Inerting, Flammability Diagram, Ignition Energy, Auto ignition, Auto-Oxidation, Adiabatic Compression, Ignition Sources, Sprays and Mists, Explosions, Detonation and Deflagration.
Electrical Safety Hazard: Electrical hazards, Fundamentals of electrical hazards, Fundamentals of electricity, Electrical shock, Control of electrical hazards.
Hazard identification Techniques:
Non Scenario Based: Checklist analysis, safety review, relative ranking, preliminary hazard analysis (PHA), fire explosion and toxicity index (FETI)
Scenario Based: Fault Tree Analysis & Event Tree Analysis, Logic symbols, methodology, minimal cut set ranking -various indices –what-if analysis/checklist analysis-hazard operability studies (HAZOP) -Hazard analysis (HAZAN) -Failure Mode and Effect Analysis (FMEA)
Safety in Process industries: Chemical process industries-Requirements and Government regulations, Hazards associated with process, Decomposition & Runaway reactions, Fault tree analysis of batch reactor, Reactive chemical hazard, Decomposition energy, Hazardous unit processes, Hazards associated with exothermic reaction –case studies, Fault tree of reactor overpressure, Components of intrinsic safety, Assessing reaction hazard,Steps to Reduce Reactive Hazards,Controlling Reactive Hazards
Safety Aspects in Process Plant Design: Process plant safety, Chemical Plant Design, Flow Diagrams, Piping and Instrumentation Diagram/Drawing (P&ID),

Control System, Alarms in Processes, Equipment and Piping, Chemical Plant Layout, Active Fire Protection, Emergency Shutdown System, pressure vessel design, standards and codes-pipe works and valves-heat exchangers-process machinery-over pressure protection, pressure relief devices and design, fire relief, vacuum and thermal relief, special situations, disposal-flare and vent systems failures in pressure system.

Reading:

1. Frank P. Lees, Loss Prevention in Process Industries, Butterworth-Hein company- UK 1990 (Vol. I, II & III).
2.D. A. Crowl and J.F. Louvar, Chemical Process Safety (Fundamentals with Applications), Prentice Hall, 2011.
3. Accident Prevention Manual for Industrial Operations, NSC, Chicago, 1982.

CH5114	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
CO1	2	-	2	3	2	2
CO2	2	2	2	3	-	2
CO3	2	1	2	3	2	-
CO4	-	-	2	3	-	-

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, Nonparameteric 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.
4. Doebelin E. O., Engineering Experimentation: Planning, Execution, Reporting, McGraw-Hill, 1995.

CH5115	CHEMICAL PROCESS SYNTHESIS	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
CO2	Synthesize a chemical process flow sheet that would approximate the real process
CO3	Synthesize Heat exchanger networks and separation trains
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
CO1	2	1	3	3	2	1
CO2	2	2	3	3	2	1
CO3	1	-	3	2	-	1
CO4	-	-	3	3	-	1

Detailed syllabus

Synthesis of steady state flow sheet: Introduction, Flow sheets, the problem of steady state flow sheeting, general semantic equation of equipment, Generalization of the method of synthesis of process flow sheet, Recycle structure of the flow sheet, separation systems.

Heuristics for process synthesis:

Raw materials and Chemical reactions, Distribution of chemicals, Separations, Heat exchangers and furnaces, pumping pressure reduction and conveying of solids

Algorithmic methods for process synthesis:

Reactor design and reactor network synthesis, Synthesis of separation trains, sequencing of ordinary distillation columns

Optimization of flow sheet 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 (rule1), 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.

Safety in Chemical plant design: Introduction, Reliability of equipment, prevention of accidents. Process Hazard analysis.

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

Reading:

1. Seider W. D., SeaderJ. D. and Lewin D. R., Product and Process Design Principles: Synthesis, Wiley, 2016.
2. Robin Smith, Chemical Process Design and Integration, John Wiley & sons Ltd,2005.
3. Bieglar L.T, Grossman E.I and Westerberg A.W., Systematic Methods of Chemical Process Design, Prentice Hall Inc., (1997)
4. Douglas J. M., Conceptual Design of Chemical Processes, McGraw Hill International, 1988.

CH5116	ENVIRONMENTAL 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	Recognize the causes and effects of environmental pollution
CO2	Analyze the mechanism of proliferation of pollution
CO3	Develop methods for pollution abatement and waste minimization
CO4	Design treatment methods for gas, liquid and solid wastes

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	1	1
CO2	3	1	3	3	1	1
CO3	3	1	3	3	1	3
CO4	3	1	3	3	1	3

Detailed syllabus

Sources of pollution: Environment and environmental pollution from chemical process industries, characterization of emission and effluents.

Standards: environmental Laws and rules, standards for ambient air, noise emission and effluents.

Pollution Prevention: Process modification, alternative raw material, recovery of by co-product from industrial emission effluents, recycle and reuse of waste, energy recovery and waste utilization. Material and energy balance for pollution minimization. Water use minimization, Fugitive emission/effluents and leakages and their control-housekeeping and maintenance.

Air Pollution Control: Particulate emission control by mechanical separation and electrostatic precipitation, wet gas scrubbing, gaseous emission control by absorption and adsorption, Design of cyclones, ESP, fabric filters and absorbers.

Water Pollution Control: Physical treatment, pre-treatment, solids removal by setting and sedimentation, filtration centrifugation, coagulation and flocculation.

Biological Treatment: Anaerobic and aerobic treatment biochemical kinetics, trickling filter, activated sludge and lagoons, aeration systems, sludge separation and drying.

Solids Disposal: Solids waste disposal - composting, landfill, briquetting / gasification and incineration.

Waste minimization: Life cycle assessment, elements of a waste minimization strategy, benefits of waste minimization, waste minimization techniques.

Need for EIA - Evolution of EIA - Concepts of EIA - Merits and demerits of EIA - Procedures - Screening, Scoping baseline data, Impact prediction - Stake holders of EIA - Public Participation in Decision making - Projects requiring Environmental Clearance - EIA methodologies - Criteria for Selection -Impact identification, measurement, interpretation and Evaluation - Impact Communication - Adhoc Methods, Checklists Methods, matrices , Networks and Overlays Methods - Cost-Benefit Analysis - Rapid EIA and Comprehensive EIA - General Framework for Environmental Impact Assessment, Characterization and site assessment. Qualitative risk analysis.

Reading:

1. Pollution Control Acts, Rules, Notifications issued there under CPCB, Ministry of Env. and Forest, G.O.I., 3rd Ed. (2006.)
2. Vallero D "Fundamentals of Air Pollution", 4 th Ed; Academic Press (2008).
3. Pichtel J "Waste Management Practices: Municipal, Hazardous and Industrial", CRC,second Edition (2014)
4. Tchobanoglous G., Burton F. L. and Stensel H.D., "Waste Water Engineering: Treatment and Reuse", 4th Ed; Tata McGraw Hill (2003).
5. Gerard Kiely, “Environmental Engineering”, Tata McGraw Hill (2007).
6. Reynolds and Richards, “Unit operations and processes in environmental engineering” PWS Publishing company, 1996.
7. N. Hanley, S.C. Bhatia, “Pollution Control in Chemical and allied industries”, CBS Publishers (2011)
8. David P. Lawrence, Environmental Impact Assessment: Practical Solutions to Recurrent Problems, John Wiley & Sons, 2003

CH5117	NUCLEAR POWER 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	Understand radioactivity, nuclear fission and fusion, interaction of particles with matter
CO2	Analyze the operationof nuclear power plants
CO3	Select materials for nuclear reactor systems
CO4	Design and operate plants for the nuclear fuel cycle with emphasis on environmental and ethical aspects.

Mapping of course outcomes with program outcomes

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

Detailed syllabus

Nuclear Reactions and radiations: Atomic structure, Radioactivity and Radio isotopes, interaction of alpha and beta particles with matter, decay chains, neutron reactions, fission process, growth and decay of fission products in a reactor with neutron burnout and continuous processing. Nuclear fission and fusion, types and classification of nuclear reactors, nuclear fuels, other reactor materials.

Nuclear Reactor theory: The neutron cycle, critical mass, neutron diffusion, the diffusion equation, slowing down of neutrons, reactor period, transient conditions and reflectors., Introduction to nuclear power systems, Thermal-hydraulics: Thermal parameters: definitions and uses. Sources and distribution of thermal loads in nuclear power reactors. Thermal analysis of nuclear fuel, Single-phase flow and heat transfer, Two-phase flow and heat transfer.

Nuclear reactor materials: General requirements (neutronic and physical) of nuclear materials: Core, structural, moderator, coolant and control rod, properties of moderator and coolant materials: graphite, beryllium, Boron, water, heavy water, liquid metals. Brief description of different systems. Selection Criteria of Materials for different systems. Materials behavior under extreme environments, radiation, high temperature, corrosion. Zr alloys and Austenitic stainless steels.

Nuclear fuel cycle:Uranium mining, milling and enrichment. Fuel reprocessing, PUREX flow sheet, Solvent extraction, Selection of solvents, Non-aqueous reprocessing. Waste management, classification of wastes, treatment of radioactive wastes, partitioning and transmutation. Deep geological disposal.

Environmental effects of nuclear Power generation. Ethical aspects of nuclear power production.

Reading:

1. Glasstone S and Alexender Seasonske, Nuclear Reactor Engineering, 3rd Edition, CBS publisher, USA, 1994.

2. Marshall, W, Nuclear Power Technology, Vol I, II, and III, Oxford University Press, New York 1983.
3. Vaidyanathan, G., Nuclear Reactor Engineering (Principles and Concepts), S. Chand Publishers, 2013
4. Lamarsh, J.R. and A.J. Baratta Introduction to Nuclear engineering, 3rd Edition, 2001
5. Kok, K.D., Nuclear Engineering Handbook, CRC Press, 2009
6. Manson B., Thomas H. Pigford,. Dr. Hans Wolfgang Levi: Nuclear Chemical Engineering, Second Edition, McGraw-Hill Professional, 1981

CH5118	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	Assess the immobilization techniques.
CO3	Analyze the kinetics of biological reactions.
CO4	Select a suitable downstream processing method for purification.

Mapping of course outcomes with program outcomes

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

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.

CH 5119	PIPING 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 the key steps in a pipeline's lifecycle: design, construction, installation and maintenance.
CO2	Draw piping and instrumentation diagrams (P&ID).
CO3	Understand codes, standards and statutory regulations.
CO4	Select pipe and pipe fittings.

Mapping of course outcomes with program outcomes

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

Detailed syllabus

Introduction to piping: piping classification, other pipe ratings, definitions of forces, moments, equilibrium, work, power, and energy

Piping components: pipe and tube products, traps, strainers, expansion joints, threaded joints, bolted flange joints, welded and brazed joints

Piping materials: material properties of piping materials, metallic materials, degradation of materials in service

Piping codes and standards: ASME, BIS, ISO standards relevant to chemical engineering.

Piping layout: Line diagram, process flow diagram, piping and instrumentation diagram, codes and standards

Application of computer-aided design to piping layout

Fabrication and installation of piping systems: introduction, fabrication, installation, Selection and application of valves, Pressure and leak testing

Flow of fluids and calculations: introduction, theoretical background, steady single-phase incompressible flow in piping, steady single-phase compressible flow in piping, single-phase flow in nozzles, venturi tubes, and orifices, steady two-phase flow

Reading:

1. McAllister E.W., Pipeline Rules of Thumb Handbook, 7th Edition, Gulf Publication, 2009.
2. Kellogg, Design of Piping System, 2nd Edition, M.W. Kellogg Co. 2009.
3. Weaver R., Process Piping Design, Vol .1 and 2, Gulf Publication, 1989.
4. Nayyar M. L., Piping Handbook, Seventh Edition, Mc-Graw Hill, 2000.

CH5211	INDUSTRIAL INSTRUMENTATION	PCC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand techniques for measurement of level, pressure.
CO2	Measure temperature using contact / non-contact techniques.
CO3	Analyze methods for torque and velocity.
CO4	Select methods for acceleration, vibration and density measurement.
CO5	Identify a suitable technique for flow measurement.

Mapping of course outcomes with program outcomes

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

Detailed syllabus

Level measurement: Gauge glass technique coupled with photo electric readout system, float type level indication, different schemes, measurement using displacer and torque tube – bubbler system. Differential pressure method. Electrical types of level gauges using resistance, capacitance, nuclear radiation and ultrasonic sensors.
Pressure measurement: Manometers, pressure gauges – Bourde type bellows, diaphragms. Electrical methods – elastic elements with LVDT and strain gauges. Capacitive type pressure gauges. Measurement of vacuum – McLeod gauge – thermal conductivity gauges – Ionization gauge cold cathode and hot cathode types – testing and calibration.
Temperature measurement: Thermometers, different types of filled in system thermometer, bimetallic thermometers. Electrical methods, signal conditioning of industrial RTDs and their characteristics –3 lead and 4 lead RTDs. Thermocouples and pyrometers.
Measurement of force torque, velocity: Electric balance – different types of load cells – magnets – elastics load cell-strain gauge load cell. Different methods of torque measurement, strain gauge, relative regular twist-speed measurement-revaluation counter- capacitive tacho-drag up type tacho D.C and A.C tacho generators – stroboscope.
Measurement of acceleration, vibration and density: Accelerometers – LVDT, piezo-electric, strain gauge and variable reluctance type accelerometers, calibration of vibration pickups, Baume scale API scale – pressure head type densitometer – float type densitometer.
Flow measurement: Volumetric flow measurement through electromagnetic, ultrasonic and vortex techniques. Mass flow measurement through Coriolis

principle. Basics of analyzers - single and multiple components through chromatography. Control valves – different types, characteristics and smart valves.

Reading:

1. William C. Dunn, Fundamentals of Industrial Instrumentation and Process Control, McGraw-Hill, 2005.
2. R. K. Jain, Mechanical and Industrial Measurements, Khanna Publishers, New Delhi, 1999.
3. E. L. Upp, Paul J. LaNasa, Fluid Flow Measurement, 2nd Edition, Gulf Professional Publishers, 2002.
4. Bela G. Liptak, Instruments Engineers Handbook, 4th Edition, CRC Press, 2003.
5. D. Patranabis, Principles of Industrial Instrumentation, Tata McGraw Hill, 1999.

CH5212	**OPTIMIZATION TECHNIQUES**	**DEC**	**3 – 0 – 0**	**3 Credits**

Pre-requisites: None

Pre-requisites: None Course Outcomes: At the end of the course, the student will be able to:

CO1	Formulate objective function for a given problem
CO2	Understand unconstrained single variable optimization and unconstrained multi variable optimization
CO3	Understand linear programming and nonlinear programming techniques
CO4	Use dynamic programming and semi definite programming for optimization

Mapping of course outcomes with program outcomes

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

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.

Applications to different processes.

Reading:

1. Edgar T.F. and D. M. Himmelblau, 'Optimization of Chemical Processes', 2nd Edition, McGraw Hill, 2001.
2. Stoecker W. F., Design of Thermal Systems, McGraw-Hill, 3rd Edition, 2011.
3. Singiresu S Rao, 'Engineering Optimization: Theory and Practice', 4th Edition, John Wiley & Sons, 2009.
4. Mohan C. Joshi and Kannan M. Moudgalya, 'Optimization: Theory and Practice', Alpha Science International, 2004.
5. Stephen Boyd, Lieven Vandenberghe, Convex optimization, Cambridge University Press, 2004.
6. P. Venkataraman, Applied Optimization with MATLAB Programming, 2nd Edition, Wiley, 2009.

CH5215	INTERNET FOR MEASUREMENT AND CONTROL	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 serial communication and parallel communication standards
CO2	Understand the protocols used with internet
CO3	Understand routers, modems and cryptography for communicating the measured data
CO4	Understand the web based calibration and data acquisition
CO5	Know the control of plants using virtual laboratories, wireless sensors and internet based tuning of the controllers

Mapping of course outcomes with program outcomes:

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

Detailed syllabus:

Industrial communication systems: Interface - Introduction, Principles of interface, serial interface and its standards. Parallel interfaces and buses

Introduction to Internet: Origin of Internet – Overview of TCP / IP layers – IP addressing – DNS – Packet switching – Routing – SMTP, POP, MIME, NNTP, ftp, Telnet, HTML, HTTP, URL, SNMP, RFCs, FYIs – STDs.

Physical Layer Aspects: Backbone network – Trunks, Routers, Bridges – Access network – MODEMs, WILL, ISDN, XDSL, VSAT.
Network Layer Aspects and Network Security: IPVG, Mobile IP – IPSEC – IPSO – Public key cryptography – digital signature standard – firewall – Secure socket Layer SSL – Secure Data Network System SDNS – Network layer security Protocol NLSP – Point to point Tunneling Protocol PPTP – SHTTP.
Measurements through Internet: Web based data acquisition – Monitoring of plant parameters through Internet – Calibration of measuring instruments through Internet.
Internet based Control: Virtual laboratory – Web based Control – Tuning of controllers through Internet. Wireless sensors for measurement and feedback control.
Internet of Things (IoT) – communication and feedback control
Demonstration using appropriate tools in the laboratory.

Reading:

1. Shuang-Hua Yang, Internet Based Control Systems, Springer, 2011.
2. Douglas E. Camer, Internet Working with TCP/IP, 3rd Edition, Prentice Hall, 1999.
3. Richard Stevens, TCP/IP Illustrated, Addison Wesley, 1999.
4. Richard E. Smith, Internet Cryptography, Addison Wesley, 1999.

CH5120	Thermoset Polymer Composites	DEC	3 – 0 – 0	3 Credits

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

CO1	Identify the suitable composite production process for an application
CO2	Characterize resin matrices and develop mathematical models for resin cure kinetics, resin cure viscosity
CO3	Characterize reinforcement fibres and calculate directional permeabilities
CO4	Carry out isothermal mould filling simulations
CO5	Characterize composite product for mechanical, thermal and morphological properties

Mapping of course outcomes with program outcomes

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

Fundamentals of Polymer Matrix Composites: Introduction of Composites, Thermoplastic and Thermotset Polymer Matrix Composites. Introduction to Resin Matrices and Reinforcement Fibres

Composite Manufacturing Process: Introduction, Material-Manufacturing Process-Property Relationship, Manufacturing of Prepeg and SMC, Molding, Resin Transfer and Vacuum Infusion molding, Compression Molding, Filament Winding

Resin Matrices and Reinforcement Fibres Characterization: Resin gelation and cure exotherm. Resin Cure Characterization & Modeling. Resin Cure Viscosity Characterization and Resin Rheokinetics. Fiber Porosity and Permeability. Reinforcement Mat Architecture

Process Modeling & Simulation on Composite Processing: Continuity and Darcys Equation, Modeling of RTM Processing, Pultrusion and Autoclave Process. General Resin Flow and Cure Model. Air Entrapment Model. Simulation Packages for Composite Processing. 1-D Resin Flow Simulation.

Testing and Characterization: Characterization and Testing of Matrix Properties, Characterization and Testing of Curing Agent, Characterization and Testing of Reinforcement Properties, Characterization and Testing of Finished Product, Physical Properties, Mechanical Properties, Morphological Characterization, Fire and Toxicity, Manufacturing Defects.

Text/Reference Books:

1.Composites Manufacturing Materials, Product, and Process Engineering by Sanjay Mazumdar

2. Fiber-reinforced Composites by P.K. Mallick

3. Process Modeling in Composite Manufacturing by S. Advani

CH5105	CHEMICAL ENGINEERING RESEARCHLAB	PCC	0– 1 – 2	2 Credits

Pre-requisites: None
Course Outcomes: At the end of the course, the student will be able to:

CO1	Estimate transfer coefficients in chemical processes
CO2	Evaluate the efficacy of process intensification techniques
CO3	Characterize corrosion properties of materials
CO4	Analyze the dynamics of chemical processes in the context of control

Mapping of course outcomes with program outcomes

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

Detailed syllabus

1. Characteristics of a Fluidized bed dryer
2. Helical Coil heat exchanger
3. Determination of Effective thermal conductivity (ETC) in granular material
4. Plate Type Heat Exchanger
5. Kinetics for solid catalyzed esterification reaction in a batch reactor
6. Reactive distillation in Packed Column
7. Ultrasonic cavitation enhanced reaction rate
8. Micro-reactor for process intensification
9. Advanced Flow Reactor
10. Membrane Separation for water purification
11. Corrosion characteristics of a metal in a given electrolyte
12. Dynamics of a spherical tank filling and emptying
13. Identification of transfer function for a three tank system.
14. Characteristics of an inverted fluidized bed

Out of all experiments, 8 experiments are offered.
Reading: Lab Manual, Online Journals.

CH5104	COMPUTATIONAL LABORATORY	PCC	0 – 1 – 2	2 Credits

Pre-requisites: None
Course Outcomes: At the end of the course, the student will be able to:

CO1	Apply numerical methods for solving engineering problems using MATLAB
CO2	Apply statistical methods for data analysis using MATLAB
CO3	Simulate process dynamics using SIMULINK
CO4	Analyze data using Design Expert

Mapping of course outcomes with program outcomes

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

Detailed syllabus:
The student will carry out simulation studies using MATLAB/SIMULINK/DESIGN EXPERT. The list of case studies include

1. Solution of linear initial value ODEs
2. Solution of linear boundary value ODEs
3. Solution of non-linear initial value ODEs
4. Solution of non-linear boundary value ODEs
5. Solution of Elliptic PDEs
6. Solution of Parabolic PDEs
7. Solution of Hyperbolic PDEs
8. Linear Regression Method
9. Non-linear Regression Method
10. Statistical analysis of data – mean, variance, distribution characteristics
11. Dynamic analysis of first and second order processes
12. Design Expert based data analysis
13. Analysis using Pipeline Studio

Out of 13 experiments, 10 experiments are offered.

Reading:

Lab Manuals.

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
CO1	2	3	1	-	3	3
CO2	2	3	1	-	1	3

Detailed syllabus

Any topic of relevance to systems and control engineering.

CH5251	ADVANCED PROCESS CONTROL	PCC	3 – 0 – 0	3 Credits

Pre-requisites: Knowledge in engineering mathematics and control

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

CO1	Develop parametric and non-parametric models for LTI systems.
CO2	Design PID controller for a given process
CO3	Analyze the controlled and manipulated variables in multivariable processes.
CO4	Implement model predictive control.

Mapping of course outcomes with program outcomes

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

Detailed syllabus

Review of basics, advanced control schemes - Cascade control, feed-forward control, ratio control, split-range control, time delay compensator, inverse response compensator, combinations of cascade and feed-forward control schemes.

Models of Discrete-Time LTI Systems - Convolution equation, Difference equations, Transfer functions. State-space models. Discretization, Sampling and Hold operations, sampling theorem.

Digital PID controllers: Position and Velocity forms; Design and implementation. IMC method. Controller design in state-space domain: Stability and transient response in closed loop.

Multivariable control - Challenges; Control pairing; Interactions in closed-loop systems; Relative Gain Array (RGA) and variants. Introduction to decentralized, decoupled control schemes.

Non-parametric models - impulse response, step response and frequency response models. Parametric model structures - ARX, ARMAX, OE, BJ and PEM – structures and identification.

Introduction to Model Predictive Control (MPC) - Concepts; Theory and implementation; Relation with LQ-control. Implementation of MPC: Step response model; State update and model prediction. Receding Horizon implementation; Variants and customizations; Issues and Challenges.

Identification of models for MPC - estimation of step response models, disturbance models for MPC; least squares estimation. Case studies.

Reading:

1. Seborg, D. E., Edgar, T. F., Millechamp, D. A., Doyle III, F. J., Process Dynamics and Control, 3rd Edition, Wiley, 2014.

2. K.J. Astrom and B. Wittenmark, Computer Controlled Systems: Theory and Design, Prentice-Hall, 2000.
3. Kannan Moudgalya, Digitial Control, Wiley, 2007.
4. Liuping Wang, Model Predictive Control System Design and Implementation using MATLAB, Springer, 2009.
5. E. F. Camacho and Carlos Bordons, Model Predictive Control, Springer, 1999.
6. Biao Huang, Ramesh Kadali, Dynamic Modeling, Predictive Control and Performance Monitoring, Springer, 2008.

CH5151	ADVANCED MASS TRANSFER	PCC	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	Classify the separation processes based on the energy requirements.
CO3	Determine the degrees of freedom using phase rule and description rule.
CO4	Compare multi-stage operations.
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
CO1	2	-	2	2	1	1
CO2	2	-	2	2	1	1
CO3	2	1	2	2	1	1
CO4	2	1	2	3	1	1
CO5	3	1	3	3	1	1

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, Choice of Column Pressure.

Binary multistage separations-general graphical approach: Straight Operating Lines, Curved Operating Lines, Extraction, Absorption, Processes without Discrete Stages, Packed tower distillation, General Properties of the y-x 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.

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.

Reactive separations: Techniques, Reactive distillation, Reactive adsorption and Reactive extraction

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.
5. S KulprathipanjaReactive Separation Processes CRC Press 1st Edition 2001

CH5152	STEADY STATE PROCESS SIMULATION	PCC	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 role and importance of property estimation methods in process simulation.
CO2	Identify degrees of freedom for a stream, a process unit and a flowsheet.
CO3	Apply suitable mathematical methods 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.
CO5	Distinguish between sequential and simultaneous convergence and convergence promotion techniques.

Mapping of course outcomes with program outcomes

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

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.

Reading:

1. Westerberg A. W., Hutchison H. P., Motard R. L. and Winter P., Process Flowsheeting, Cambridge University Press, 2011.
2. Ivan Dano Gill Chaves, Javier Ricardo Guevara Lopez, Jpose Luis Garcia Zapata, Alexander Leguizamon Robayo and Gerardo Rodrigue Nino, Process Analysis and Simulation in Chemical Engineering, Springer, 2016.
3. Babu B. V., Process Plant Simulation, Oxford University Press, 2004.
4. Mariano Martin Martin, Introduction to Software for Chemical Engineers, CRC Press, 2015.

CH5161	DATA ANALYTICS	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Demonstrate proficiency with statistical analysis of data.
CO2	Use inferential statistics for decision making
CO3	Apply supervised learning for classification and regression problems
CO4	Apply unsupervised learning for clustering

Mapping of course outcomes with program outcomes

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

Detailed Syllabus

Introduction

Data Quality and Preprocessing: Distance measures, Dimensionality reduction, Principal Component analysis (PCA)

Descriptive Statistics: Frequency tables, graphs - bar graph, relative frequency tables and graphs), grouped data, histograms, Ogives, Stem and leaf plots, Box plots, Pareto diagram, dot diagram

Measures of Central Tendency and Dispersion - Arithmetic Mean, Median and Mode; Variance, Standard deviation, quartlies, range, mean absolute deviation, Z scores, coefficient of variation. Normal Distribution

Confidence Interval Estimation

Inferential Statistics: Hypothesis Testing, Analysis of Variance (ANOVA)

Machine Learning

Supervised learning: Least squares regression, Ridge regression, logistic regression, k-Nearest Neighbours Algorithm, Bias – Variance Dichotomy, Linear Discriminant analysis, Classification and Regression Trees, Support Vector Machines, Neural networks, Deep learning.

Unsupervised learning: Cluster Analysis – K-Means, Hierarchical, DBSCAN

Reading:

1. Douglas C. Montgomery, George C. Runger, Applied Statistics and Probability for Engineers, Third Edition, John Wiley & Sons Inc., 2003.
2. Trevor Hastie, Robert Tibshirani, Jerome Friedman, The Elements of Statistical Learning, Springer, 2009.
3. Tomáš Horváth, André C. P. L. F. de Carvalho, João Mendes Moreira, A General Introduction to Data Analytics, Wiley, 2019.
4. Pang-Ning Tan, Michael Steinbach, Anuj Karpatne, Vipin Kumar, Introduction to Data Mining, Second Edition, Pearson, 2019.
5. Ethem Alpaydın, Introduction to Machine Learning, Third Edition, MIT Press, 2014.

CH5162	PROCESS SCHEDULING AND UTILITY INTEGRATION	DEC	3 – 0 – 0	3 Credits

Prerequisites: Computational Techniques.

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

CO1	Identify the objectives of scheduling problem
CO2	Develop a model for batch process scheduling
CO3	Integrate process scheduling and resource conservation
CO4	Design and synthesize batch plants

Mapping of the Course Outcomes with Program Outcomes

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

Detailed Syllabus:

Introduction to Batch Chemical Processes: Definition of a batch process, Operational philosophies, Types of batch plants, Recipe representations, Batch chemical process integration.

Short-Term Scheduling: Effective technique for scheduling of multipurpose and multi-product batch plants, Different storage policies for intermediate and final products, Evolution of multiple time grid models in batch process scheduling, Short-term scheduling of multipurpose pipeless plants, Planning and scheduling in biopharmaceutical industry.

Resource Conservation: Integration of batch process schedules and water allocation network, Water conservation in fixed scheduled batch processes, Wastewater minimization in multiproduct batch plants: single contaminants, Storage design for maximum wastewater reuse in batch plants, Wastewater minimization in multipurpose batch plants: multiple contaminants, Wastewater minimization using multiple storage vessels, Wastewater minimization using inherent storage, Zero effluent methodologies,

Heat integration in multipurpose batch plants: direct and indirect heat integration, Simultaneous optimization of energy and water use in multipurpose batch plants, Flexibility analyses and their applications in solar-driven membrane distillation desalination system designs, Automated targeting model for batch process integration.

Design and Synthesis: Design and synthesis of multipurpose batch plants, Process synthesis approaches for enhancing sustainability of batch process plants, Scheduling and design of multipurpose batch facilities: Periodic versus non periodic operation mode through a multi objective approach, Mixed-integer linear programming model for optimal synthesis of polygeneration systems with material and energy storage for cyclic loads.

Reading:

1. Thokozani Majozi, Esmael Reshid Seid, Jui-Yuan Lee "Synthesis, Design, and Resource Optimization in Batch Chemical Plants", CRC Press Taylor & Francis, 2015.
2. Thokozani Majozi "Batch Chemical Process Integration - Analysis, Synthesis and Optimization", Spinger, 2010.
3. Gintaras V. Reklaitis, Aydin K. Sunol, David W. T. Rippin, Oner Hortacsu "Batch Processing Systems Engineering", Spinger, 1996.
4. Mariano Martin, Introduction to Software for Chemical Engineers, CRC Press, 2015.

CH5162	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	Assess competing membrane processes.
CO3	Understand the methods of membrane preparation.
CO4	Select a membrane and membrane process for a given application.
CO5	Evaluate the flux of solvent and solute through membrane.

Mapping of course outcomes with program outcomes

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

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.

4. Richard W. Baker, Membrane Technology and Research, Inc. (MTR), Newark, California, USA, 2004.

CH5164	MOLECULAR THERMODYNAMICS	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 intermolecular forces concept to thermodynamic properties
CO2	Apply statistical thermodynamic models for phase equilibrium calculations
CO3	Evaluate applicability of activity coefficient models for non-ideal systems
CO4	Solve problems involving multiphase equilibrium

Mapping of course outcomes with program outcomes

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

Detailed syllabus

Classical Thermodynamics: First and Second laws, Property relationships, Ideal and Non-ideal gases equation of state.

Intermolecular forces theory: Potential Energy functions, Electrostatic forces, Polarizability & Induced dipoles, Mie's potential-energy function for non-polar molecules, Structural effects, Chemical Forces.

Statistical thermodynamics: Ensembles, Partition function, Partition function for ideal gases, Equation of state, Virial equation of state for non-ideal gases.

Fugacities in Gas Mixtures: Fugacities from Virial equation, Virial coefficients from potential functions and corresponding state correlations.

Fugacities in Liquid Mixtures: The Ideal solution, excess functions, activity coefficients and their evaluation, Wilson, NRTL, UNIQUAC equations, van Laar theory, Scatchard-Hildebrand theory, Lattice model, two liquid theory, group contribution method and chemical theory.

Applications: Vapor-liquid equilibrium, Solubility of gases in liquids, Solubility of solids in liquids, liquid-liquid equilibrium

Reading:

1. Prausnitz J. M., Lichtenthaler R. N., Azevedo E. G., Molecular Thermodynamics of Fluid-Phase Equilibria, 3rd Edition, Prentice-Hall, 1999.
2. Modell M., Reid R. C, Thermodynamics and its Applications, Prentice-Hall, 1983.

3. Smith J. M., Van Ness H. C., Abbott M.M., Introduction to Chemical Engineering Thermodynamics, 5th edition, McGraw Hill, 2001.
4. Tester J. W., Modell M., Thermodynamics and its Applications, third edition, Prentice-Hall, 1997.
5. Sandler S. I., An Introduction to Applied Statistical Thermodynamics”, Wiley, 2011.

CH5165	COMPUTATIONAL FLUID DYNAMICS	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 governing equations of fluid flow and heat transfer, and classify them
CO2	Discretize the equations using Finite difference and volume formulation
CO3	Solve the discretized equations using different techniques
CO4	Implement pressure velocity coupling algorithms
CO5	Understand grid generation techniques

Mapping of course outcomes with program outcomes

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

Detailed syllabus

Introduction – CFD approach, Need for CFD.
Governing equations of fluid flow and heat transfer - Laws of conservation: Mass – Momentum - Energy, Initial and boundary conditions - Conservative form – Differential and Integral forms of general transport equations – Classification of physical behaviours – Classification of fluid flow equations.
Discretization of equations – Finite difference / volume methods – 1D, 2D and 3D Diffusion problems - Convection and diffusion problems - Properties of discretisation schemes- Central, upwind, hybrid and higher order differencing schemes.
Solution methods of discretised equations- Tridiagonal matrix algorithm (TDMA)- Application of TDMA for 2D and 3D problems – Iterative methods – Multigrid techniques.
Pressure – velocity coupling algorithms in steady flows – Staggered grid – SIMPLE, SIMPLEC and PISO - Unsteady flows- Explicit scheme, Crank Nicholson scheme, fully implicit scheme
Turbulence modelling - Prantl mixing length mode - One equation model, *k* - *ε* model, RSM equation model - Applications.
Structured and unstructured grids – Grid generation methods

Reading:

1. H. K. Versteeg, W. Malalasekera, An Introduction to Computational Fluid Dynamics - The finite volume method, 2nd Edition, Prentice Hall 2007.

2. T. J. Chung, Computational Fluid Dynamics, 2nd Edition, Cambridge University Press, 2010.
3. C. Hirch, Numerical Computation of internal and external flows, 2nd Edition, Wiley, 2007.
4. J. D. Anderson Jr., Computational Fluid Dynamics - The basics with Applications, McGraw Hill, 1995.
5. J. H. Ferziger, M. Peric, Computational Methods for Fluid Dynamics, Springer, 2002.

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	Identify the scope for process intensification in chemical processes.
CO2	Implement methodologies for process intensification
CO3	Understand scale up issues in the chemical process.
CO4	Solve process challenges using intensification technologies.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	3	2	1	2
CO2	-	2	3	2	1	2
CO3	3	2	3	3	1	1
CO4	2	2	3	3	1	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, Sono-crystallization, Reactive separations, Superctrical fluids.

Reading:

1. Stankiewicz, A. and Moulijn, (Eds.), Reengineering the Chemical Process Plants, Process Intensification, Marcel Dekker, 2003.
2. Kamelia Boodhoo (Editor), Adam Harvey (Editor),Process Intensification Technologies for Green Chemistry: Engineering Solutions for Sustainable Chemical Processing, Wiley, 2013.
3. Segovia-Hernández, Juan Gabriel, Bonilla-Petriciolet, Adrián (Eds.)Process Intensification in Chemical Engineering Design Optimization and Control, Springer, 2016.
4. Reay, Ramshaw, Harvey, Process Intensification, Engineering for Efficiency, Sustainability and Flexibility, Butterworth-Heinemann, 2013.

CH5167	ELECTROCHEMICAL 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	Analyze an electrochemical process through mathematical approach
CO2	Characterize electrochemical systems using analytical instruments
CO3	Develop unit operations involving electrochemical applications
CO4	Design batteries and fuel cells for power generation and storage

Mapping of course outcomes with program outcomes

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

Detailed syllabus

Electrode Potentials and Thermodynamics of Cells: basic electrochemical thermodynamics, free energy, cell emf and Nernst equation, half-cell reactions and redox potentials, reference electrodes

Electrode Kinetics: Arrhenius equation and potential energy surfaces, transition state theory, Butler-Volmer model of electrode kinetics, current-over potentials, Tafel plots

Electroplating: electrochemistry fundamentals, anode-cathode reactions, Faraday's law of electrolysis, current efficiency, current density, current distribution, voltage-current relationship, over potential and over voltage, surface preparation, electrolytic metal deposition, Electrolyte, types of electroplating processes and coatings

Anodizing: Aluminum anodizing, nanopores in anodized alumina,

Electropolishing: Types of metals and electrolytes, characteristics of electropolished surfaces, electropolishing vs mechanical polishing, applications

Batteries: Basic concepts, battery characteristics, classification of batteries– primary, secondary and reserve batteries, modern batteries - construction, working and applications of zinc–air, nickel-metal hydride and $Li\text{-}MnO_2$ batteries

Fuel cells: Introduction, types of fuel cells - alkaline, phosphoric acid, molten carbonate, solid polymer electrolyte and solid oxide fuel cells, construction and working of methanol-oxygen fuel cell

Corrosion Protection: Sacrificial anodes, impressed current techniques, polarization characteristics, galvanic series, coatings

Reading:

1. Bard A. J., Faulkner L. R., Electrochemical Methods: Fundamentals and Applications, Second Edition, Wiley (2010).
2. Bagotsky V.S., Skundin A. M., Electrochemical Power Sources: Batteries, Fuel Cells, and Supercapacitors (The ECS Series of Texts and Monographs) (2015).

3. Fontana M. G., Corrosion Engineering, Third Edition, McGraw-Hill (2008).
4. Solanki C. S., Solar Photovoltaics – Fundamentals, Technologies and Applications, PHI Publishers (2015).
5. West, Alan C., Electrochemistry and Electrochemical Engineering: An Introduction, Columbia University, 2013.
6. Hart, Lenny, Electrochemistry and Electrochemical Engineering, Larsen and Keller, 2017

CH5168	**INDUSTRIAL WASTEWATER TREATMENT**	**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 principles and operation of water treatment systems
CO2	Appraise the suitability of the design of treatment plants and unit processes
CO3	Evaluate process operations and performance
CO4	Comprehend coagulation, flocculation, and sedimentation, filtration, and disinfection processes

Mapping of course outcomes with program outcomes

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

Detailed syllabus

Introduction: Sources of water, necessity of treatment, Critical Water quality parameters, water quality guidelines and standards for various water uses.

Unit operations: Principles and design of aeration systems – two film theory, water in air system, air in water system.

Intake structures: Different types, design criteria

Principles of sedimentation: Types of settling and settling equations, design criteria and design of settling tanks.

Principle of Coagulation and Flocculation: types of coagulants, coagulant aids, coagulation theory, optimum dose of coagulant, design criteria and numerical examples

Filtration: Theory, types, hydraulics of filter bed, design criteria and design of filters, filter backwash, operational problems and trouble shooting.

Adsorption Process: Types, factors affecting adsorption, kinetics and equilibrium – different isotherm equations and their applications

Ion Exchange: principles, breakthrough capacities, column design, operation and regeneration.

Unit processes: disinfection – different types, disinfectants, factors affecting disinfection, methods of disinfection, chemistry of chlorination. Water Softening – Ions causing hardness, Langelier index, various methods. Fluoridation and defluoridation – Principles and design

Trace organic contaminants in water supplies and their removal.

Advanced treatment processes: Membrane processes, Ceramic and polymeric membrane processes; Microfiltration, ultrafiltration, reverse osmosis, Electrochemical wastewater treatment. Photocatalytic and Fenton processes, Hybrid technologies for wastewater treatment.

Biological treatment:Fundamentals of biological wastewater treatment: Composition and classification of microorganisms, bacterial growth and energetics, Suspended growth biological treatment processes for BOD, Nitrogen and Phosphorous removal, Attached growth and combined biological treatment processes.

Reading:

1. MetCalf, Eddy, Wastewater engineering, Treatment and Reuse, Tata McGraw-Hill, 2003.
2. S.J. Arceivala, S.R. Asolekar, Wastewatwer Treatment for Pollution Control and Reuse, 3rd edition, Tata McGraw-Hill, 2007.
3. N. Hanley, S.C. Bhatia, Pollution Control in Chemical and allied industries, CBS Publishers, 2010.
4. C.A. Sastry, M.A. Hashim, P.Agamuthu, Waste Treatment Plants, Narosa Publishing House, 1995.
5. Tchobanoglous G., Burton F. L. and Stensel H.D., "Waste Water Engineering: Treatment and Reuse", 4th Ed; Tata McGraw Hill (2002).
6. Fair, G.M., Geyer J.C and Okun, Water and Waste water Engineering" Vol II, John Wiley Publications.
7. Mika Sillanpää, Marina Shestakova, Electrochemical Water Treatment Methods: Fundamentals, Methods and Full Scale Applications, Butterworth-Heinemann, 19-Jun-2017 - Technology & Engineering - 310 pages.

CH5169	ENERGY AUDIT AND CONSERVATION	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	Plan energy conserving strategies
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
CO1	3	2	1	3	1	1
CO2	3	2	2	3	-	-
CO3	3	1	1	3	-	-
CO4	3	1	1	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.

Use of alternate energy: Solar energy, Wind energy, Nuclear energy, Biomass, Geothermal energy, Future Energy Alternatives.

Pinch Analysis and Process Heat Integration

Energy Management Key Performance Indicators and Energy Dashboards

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.
5. A.P Rossiter, B.P Jones, “Energy Management and Efficiency for the process industries”, AIChE, Wiley (2015)

CH5170	**PETROLEUM REFINING**	**DEC**	**3 – 0 – 0**	**3 Credits**

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

CO1	Understand the chemistry and properties of different crude oils and feedstock
CO2	Understand the primary and secondary processes in refining
CO3	Evaluate the effects of process variables on the properties of the products, yield and selectivity
CO4	Select suitable technologies to be used in Refinery & Petrochemical processes
CO5	Analyze Hydrogen production processes and sulphur recovery processes

Mapping of course outcomes with program outcomes

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

Detailed syllabus:

Global crude oil and Refining scenario Growth of Indian Refining industry, Challenges faced by Indian Refineries and mitigation measures. Characterization of crude oil and refinery products-physical properties, chemical properties.
Crude distillation process- atmospheric distillation unit (ADU)-process description-design characteristics; vacuum distillation unit (VDU)-process description-calculating tower loading; Crude Desalting, Solvent Extraction;
Thermal Processes: Steam Cracking, Visbreaking, Delayed Coking, Fluid / Flexi Coking;
Catalytic processes: Catalytic cracking- Fixed-bed, moving-bed, Fluidized-bed processes-process variables-catalysts; Catalytic reforming- Feedstock, Catalysts, Process flow schemes;
Hydrocracking- Hydrotreating and Hydrocracking-Flow schemes, Chemistry-catalysts-design and operation.
Light end processes- alkylation, isomerization and polymerization-process variables, feedstock, reactor design
Hydrogen Production-Process variables, Commercial processes, Catalysts, Hydrogen Purification. Sulphur recovery processes
Product Blending and Correlations; Petro-chemical product families; Synergy between Refinery
and Petrochemicals; Profitability, Pricing, and Cost of petrochemical products.

Reading:

1. Speight, J. G. and B. Ozum, Petroleum Refining Process, Marcel Dekker, 2002.
2. Mall, I.D., Petrochemical Process Technology, Macmillan India Ltd., 2006.
3. Surinder Parkash, Refining Processes Handbook, Gulf Professional Pub, 2003.

4. Gary, J.H. and G. E. Handwerk, Petroleum Refining: Technology and Economics, 4th Ed., Marcel Dekker, 2001.
5. Hsu, C.S. and P. R. Robinson, Practical Advances in Petroleum Processing, Springer, 2006.
6. Serge Raseev, Thermal and Catalytic Processes in Petroleum Refining, CRC Press, 2003.
7. W.S.Gruese and D.R. Stevens, Chemical Technology of Petroleum, McGraw Hill, 1960.
8. Bhaskara B K, Modern Petroleum Refining Process, 5th Edition, Oxibh, 2008.

CH5261	NONLINEAR DYNAMICS& CONTROL	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 nonlinear systems and their dynamics
CO2	Apply realization theory to linear systems and stability concepts
CO3	Understand nonlinear control and the concepts of controllability and observability
CO4	Apply Lyapunov method for stability of linear and nonlinear systems

Mapping of course outcomes with program outcomes

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

Detailed syllabus

Introduction to nonlinear systems, Phase plane analysis – generalization of phase plane behavior. Limit cycle behavior of nonlinear systems.

Nonlinear dynamics –Bifurcation and orbit diagrams. Stability of fixed point solutions. Cascade of period doublings. Bifurcation behavior of single ODE systems. Bifurcation behavior of two state systems – limit cycle behavior, Hopf bifurcation.

Realization theory – Realization of LTI systems, realization of bilinear systems, examples. Stability and the Lyapunov method – local stability, Lyapunov theory.

Introduction to nonlinear control – importance. Singular perturbation theory, Properties of ODE systems with small parameters, Nonstandard singularly perturbed systems with two time scales, Singularly perturbed systems with three or more time scales.

Controllability and Observability: controllability and Observability of LTI Systems, local Controllability and Observability of Nonlinear Systems.

Stability and The Lyapunov Method: Stability Notions, BIBO (Bounded-input-bounded-output)Stability Conditions for LTI Systems, L_2-gain of Linear and Nonlinear Systems, the Small-gain Theorem, Asymptotic or Internal Stability of Nonlinear Systems.

Lyapunov Function, Lyapunov Theorem for LTI Systems. Feedback and Input-output Linearization of Nonlinear Systems - Relative Degree, Exact Linearization via State Feedback, Nonlinear Coordinates Transformation and State Feedback, The State-space Exact Linearization Problem for SISO Systems. Exact and Input-output Linearization. Exact Linearization via State Feedback.

Reading:

1. K.M. Hangos, J. Bokor, G. Szederkényi, Analysis and Control of Nonlinear Process Systems, Springer, 2004.

2. Jean-Jacques E Slotine, Weiping Li, Applied Nonlinear Control, Prentice-hall, 1991.
3. Daizhan Cheng Xiaoming Hu Tielong Shen, Analysis and Design of Nonlinear Control Systems, Springer, 2010.
4. Michael Baldea, Prodromos Daoutidis, Dynamics and Nonlinear Control of Integrated Process Systems, Cambridge University Press, 2012.
5. H. K. Khalil, Nonlinear Systems, 3rd Edition, Englewood Cliffs, NJ: Prentice Hall, 2001.
6. B. Wayne Bequette, Process Dynamics: Modeling, Analysis and Simulation, Prentice Hall, 1998.

CH5262	SOFT-COMPUTING 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	Understand the concept of neural networks
CO2	Use neural networks to control the process plants
CO3	Develop fuzzy logic based controllers for different processes
CO4	Combine fuzzy logic with neural networks for plant control
CO5	Design controllers using genetic algorithms

Mapping of course outcomes with program outcomes

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

Detailed syllabus

Introduction to Neural Networks: Artificial Neural Networks: Basic properties of Neurons, Neuron Models, and Feed forward networks. Computational complexity of ANNs.

Neural Networks Based Control: ANN based control: Introduction: Representation and identification, modeling the plant, control structures – supervised control, Model reference control, Internal model control, Predictive control: Examples – Inferential estimation of viscosity an chemical process, Auto turning feedback control, industrial distillation tower.

Introduction to Fuzzy Logic: Fuzzy Controllers: Preliminaries – Fuzzy sets and Basic notions – Fuzzy relation calculations – Fuzzy members – Indices of Fuzziness – comparison of Fuzzy quantities – Methods of determination of membership functions.

Fuzzy Logic Based Control: Fuzzy Controllers: Preliminaries – Fuzzy sets in commercial products – basic construction of fuzzy controller – Analysis of static properties of fuzzy controller – Analysis of dynamic properties of fuzzy controller – simulation studies – case studies – fuzzy control for smart cars.

Neuro – Fuzzy and Fuzzy – Neural Controllers: Neuro – fuzzy systems: A unified approximate reasoning approach – Construction of role bases by self-learning: System structure and learning.

Introduction to Genetic algorithms. Controller design using genetic algorithms.

Reading:

1. Bose and Liang, Artificial Neural Networks, Tata McGraw Hill, 1996.
2. Huaguang Zhang, Derong Liu, Fuzzy Modeling and Fuzzy Control, Birkhauser Publishers, 2006.
3. Kosco B, Neural Networks and Fuzzy Systems: A Dynamic Approach to Machine Intelligence, Prentice Hall of India, New Delhi, 1992.

4. Lakshmi C. Jain, N. M. Martin, Fusion of Neural Networks, Fuzzy Systems and Genetic Algorithms: Industrial Applications, CRC Press, 1998.
5. Muhammet Ünal, AyçaAk, VedatTopuz, Hasan Erdal, Optimization of PID Controllers using Ant colony and Genetic Algorithms, Springer, 2013.
6. S. N. Sivanandam and S. N. Deepa, Principles of Soft Computing, John Wiley & Sons, 2007.

CH5263	DISTILLATION CONTROL	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 distillation operations
CO2	Choose control scheme for distillation control
CO3	Design control schemes for control of pressure, temperature, flow and level in the column
CO4	Design control schemes in the presence of process interactions
CO5	Design control schemes for different types of distillation processes

Mapping of course outcomes with program outcomes:

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

Detailed syllabus:
Introduction to distillation operations - Binary separation concepts - McCabe - Thiele diagram - other parameters in binary distillation - Introduction to multi component separation - Minimum reflux - Number of plates calculations. Formulation of the Control Problem, Tower Internals, Flooding, Tray Hydraulics, Inverse Response in Bottoms Level, Composition Dynamics.
Steady state calculations for control structure selection – control structure alternatives, feed composition sensitivity analysis, temperature control tray selection.
Classification of control schemes for distillation - Control of composition, choice of temperature measurement to infer composition. Distillate Composition Control - Constant Boil up, Constant Bottoms Flow, Operating Lines, Temperature Profiles, Feed Composition Disturbances, Bottoms Composition Control, Propagation of Variance in Level Control Configurations, Level Control in Direct Material Balance Configurations
Pressure control and condensers. Feed forward control - feed flow and composition, internal reflux control, extreme feed forward, feed forward for bottoms level and column pressure, product specifications.
Dynamic modeling and simulation. Pairing and Interaction in distillation - Proper pairing in single and dual composition control. Double-End Composition Control: Defining the Problem, Options for Composition Control, Relative Gain, Relative

Gains from Open Loop Sensitivities, Relative Gains for Other Configurations, Ratios for Manipulated Variables, Effect of Operating Objectives, Model predictive control.
Control of extractive distillation process, columns with partial condensers, heat-integrated distillation columns, azeotropic columns and reactive distillation process.

Reading:

1. Cecil L. Smith, Distillation Control: An Engineering Perspective", Wiley, 2012.
2. William L. Luyben, Distillation Design and Control using ASPEN Simulation, 2nd Edition, Wiley, 2013.
3. Lanny Robins, Distillation Control, Optimization and Tuning, CRC Press, 2011.
4. W.L. MaCabe, J.C.Smith and P. Harriott, "Operations of Chemical Engineering", 5th Edition, McGraw Hill, 1993.
5. Urmila Diwekar, Batch Distillation: Simulation, Optimal Design, and Control, 2nd Edition, CRC Press, 2012.

CH5153	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 Mixer, splitter, heat exchangers, pumps, compressors, flash units, reactors, distillation columns, calculator block and solid handling units.
CO3	Apply sensitivity, design specification and case study tools in Aspen.
CO4	Optimize process flowsheets using sequential modular approach as well as equation-oriented approach.
CO5	Carry out dynamic simulation, pinch analysis and cost estimation using suitable examples.
CO6	Solve linear and non-linear programming problems.

Mapping of course outcomes with program outcomes

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

Detailed syllabus

Solve the following steady state simulation exercises using **Aspen, MATLAB & GAMS**:

1. Physical property estimations.
2. Simulation of individual units like, mixers, splitters, heat exchangers, flash columns and reactors
3. Design and rating of heat exchangers
4. Design and rating of distillation columns.
5. Mass and Energy balances.
6. Handling user specifications on output streams – Sensitivity and design Spec tools.
7. Simulation of a flowsheet
8. Simulation exercises using calculator block
9. Optimization Exercises
10. Simulation using equation oriented approach
11. Simulation of processes involving solids
12. Pinch analysis

CH5154	FLOW MODELING AND SIMULATION LAB	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 heat/mass/momentum balance equations using COMSOL Multiphysics/Ansys Software
CO2	Visualize flow/temperature/concentration distribution in coupled phenomena between heat, mass & momentum transfer
CO3	Design equipment for fluidized beds, heat exchangers and microfluidic devices.
CO4	Optimize operating conditions for of a given processes based on flow behavior.

Mapping of course outcomes with program outcomes

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

Detailed syllabus

Simulation using COMSOL / ANSYS CFD

1. Hagen-Poisuelle flow
2. Flow past a cylinder
3. Flow through micro-channels with obstacles like air bubbles
4. RTD determination in tubular reactor
5. Conversion in PFR/Tubular reactor
6. Fluidization
7. Flow through Packed bed
8. Lid-driven cavity flow
9. Reaction & Diffusion in and around a catalyst particle
10. Effective thermal diffusivity/conductivity of granular material
11. Rayleigh Bernard Convection
12. Natural convection between vertical walls
13. Double pipe heat exchanger

Out of all experiments, 10 experiments are offered.

CH5291	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
CO1	2	3	1	-	3	3
CO2	2	3	1	-	1	3

Detailed syllabus

Any topic of relevance to systems and control engineering.

CH6142	**COMPREHENSIVE VIVA-VOCE**	**PCC**	**0 – 0 – 0**	**2 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**
CO1	1	1	1	1	2	1
CO2	1	1	1	1	2	1

Detailed syllabus

Process Control courses of I year.

CH6149	DISSERTATION PART-A		0 – 0 – 0	9 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
CO5	Demonstrate the progress of dissertation work

Mapping of course outcomes with program outcomes

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

CH6299	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 outcomes of dissertation work

Mapping of course outcomes with program outcomes

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	3	3	3	1	1
CO2	3	3	3	3	1	1
CO3	3	3	3	2	1	1
CO4	3	3	3	3	1	1