

ANNA UNIVERSITY, CHENNAI
NON- AUTONOMOUS COLLEGES
AFFILIATED TO ANNA UNIVERSITY
M. TECH. CHEMICAL ENGINEERING
REGULATIONS 2025

PROGRAMME OUTCOMES (POs):

PO	Programme Outcomes
PO1	An ability to independently carry out research /investigation and development work to solve practical problems
PO2	An ability to write and present a substantial technical report/document.
PO3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

PROGRAMME SPECIFIC OUTCOMES(PSOs):

PSO	Programme Specific Outcomes
PSO1	Apply core chemical engineering principles to design, analyze, and optimize chemical processes and systems.
PSO2	Demonstrate practical skills in process control, separation, and intensification, with industry exposure through projects and training.



ANNA UNIVERSITY, CHENNAI

POST GRADUATE CURRICULUM (NON.AUTONOMOUS AFFILIATED INSTITUTIONS)

Programme: M. Tech. Chemical Engineering

Regulations: 2025

Abbreviations:

BS – Basic Science (Mathematics)
ES – Engineering Science (General (**G**),
 Programme Core (**PC**), Programme
 Elective (**PE**))

SD – Skill Development

SL – Self Learning

L –Laboratory Course

T – Theory

LIT –Laboratory Integrated Theory

PW – Project Work

TCP –Total Contact Period(s)

SEMESTER I

S. No.	Course Code	Course Title	Type	Periods per week			TCP	Credits	Category
				L	T	P			
1.	CX25101	Numerical Methods for Chemical Engineers	T	3	1	0	4	4	ES (PC)
2.	CX25102	Advanced Transport Phenomena	T	3	0	0	3	3	ES (PC)
3.	CX25103	Advanced Reaction Engineering	T	3	0	0	3	3	ES (PC)
4.	CX25104	Advanced Process Control	LIT	3	0	2	5	4	ES (PC)
5.	CX25105	Separation Processes	LIT	3	0	2	5	4	ES (PC)
6.	CX25106	Technical Seminar	---	0	0	2	2	1	SD
Total Credits							22	19	

SEMESTER II

S. No.	Course Code	Course Title	Type	Periods per week			TCP	Credits	Category
				L	T	P			
1.	CX25201	Process Intensification	T	3	0	0	3	3	ES (PC)
2.	CX25202	Modelling of Chemical Processes	T	3	1	0	4	4	ES (PC)
3.	CX25203	Advanced Thermodynamics for Chemical Engineers	T	3	0	0	3	3	ES (PC)
4.	CX25204	Chemical Process Optimization	T	3	0	0	3	3	ES (PC)
5.	---	Programme Elective I	T	3	0	0	3	3	ES (PE)
6.	---	Industry Oriented Course I	---	1	0	0	1	1	SD
7.	CX25205	Virtual Laboratory	L	0	0	2	2	1	SD
8.	CX25206	Industrial Training [#]	---	---	---	---	---	---	SD
9.	---	Self-Learning Course	---	-	-	-	-	1	-
Total Credits							20	19	

Evaluation will be done in third semester for the summer internship.

SEMESTER – III

S. No.	Course Code	Course Title	Type	Periods per week			TCP	Credits	Category
				L	T	P			
1.	---	Programme Elective - II	T	3	0	0	3	3	ES (PE)
2.	---	Programme Elective - III	T	3	0	0	3	3	ES (PE)
3.	---	Programme Elective - IV	T	3	0	0	3	3	ES (PE)
4.	---	Programme Elective - V	T	3	0	0	3	3	ES (PE)
5.	---	Industry Oriented Course II	---	1	0	0	1	1	SD
6.	CX25301	Project Work I	---	0	0	12	12	6	SD
7.	CX25206	Industrial Training [#]	---	---	---	---	---	2	SD
Total Credits							25	21	

SEMESTER IV

S. No.	Course Code	Course Title	Type	Periods per week			TCP	Credits	Category
				L	T	P			
1.	CX25401	Project Work II	---	0	0	24	24	12	SD
Total Credits							24	12	

PROGRAMME ELECTIVE COURSES (PE)

S. No.	Course Code	Course Title	Periods			Total Contact Periods	Credits
			L	T	P		
1.	CX25C01	Sustainable Management	3	0	0	3	3
2.	CX25C02	Design of Experiments	2	0	2	4	3
3.	CX25C03	Industrial Instrumentation	3	0	0	3	3
4.	CX25001	Biochemical Engineering	3	0	0	3	3
5.	CX25002	Waste to Energy	3	0	0	3	3
6.	CX25003	Fluidization Engineering	3	0	0	3	3
7.	CX25004	Nanocomposites	3	0	0	3	3
8.	CX25005	Thermal processing of food Products	3	0	0	3	3
9.	CX25006	Bioprocess Technology	3	0	0	3	3
10.	CX25007	Computational Fluid Dynamics	3	0	0	3	3
11.	CX25008	Water and Wastewater Technologies	3	0	0	3	3
12.	CX25009	Biomass Conversion Techniques	3	0	0	3	3
13.	CX25010	Polymer Processing Technology	3	0	0	3	3
14.	CX25011	Business Analytics	3	0	0	3	3
15.	CX25012	Chemical Processes and Pollution Control	3	0	0	3	3
16.	CX25013	Risk Analysis and Management	3	0	0	3	3
17.	CX25014	Project Engineering of Process Plants	3	0	0	3	3
18.	CX25015	Operations Research	3	0	0	3	3
19.	CX25016	Safety and Environment in Chemical Industries	3	0	0	3	3
20.	CX25017	AI and ML in Chemical Engineering	3	0	0	3	3
21.	CX25018	Data Analytics in Process Industries.	3	0	0	3	3

Semester I

CX25101	Numerical Methods for Chemical Engineers	L	T	P	C
		3	1	0	4
<p>Course Objective: Apply the numerical techniques to solve the simultaneous equation, Ordinary Differential and Partial differential equations.</p>					
<p>Finding the Roots: Mathematical models for solving engineering problems, programming and software; Finding roots of a single equation, Direct methods (bisection, Regula falsi), Indirect methods (Newton-Raphson, Secant method)</p> <p>Activity: solving the numerical problems using MATLAB /Micro soft office Excel.</p>					
<p>Solution for Simultaneous Equations: Types of matrices and matrix operation rules, Solution for linear system of simultaneous equations, Direct methods (Gauss Elimination, Gauss Jordan), Iterative methods (Gauss-Jacobi and Gauss- Seidel); Overview of non-linear system of equations.</p> <p>Activity: solving the numerical problems using MATLAB /Micro soft office Excel</p>					
<p>Interpolation and Regression Analysis:Newton's divided, difference interpolating polynomial, Linear, polynomial, quadratic rules, Lagrange interpolating polynomial, Linear, polynomial Regression.</p> <p>Activity: solving the numerical problems using MATLAB /Micro soft office Excel.</p>					
<p>Optimization: One-Dimensional Unconstrained Optimization, Golden section search and Newton's Method; Overview on multidimensional unconstrained optimization, gradient and non-gradient methods; Constrained optimization, Simplex method;</p> <p>Activity: solving the numerical problems using MATLAB /Micro soft office Excel.</p>					
<p>Integration and Differentiation: Newton cotes Integration, Trapezoid method, Simpson's 1/3rd rule, Simpson's 3/8th rule; Numerical differentiation, Forward, Backward, Central difference methods.</p> <p>Activity: solving the numerical problems using MATLAB /Micro soft office Excel.</p>					
<p>Ordinary Differential Equations: Initial Value Problems, Euler, Predictor, corrector, Runge-Kutta methods; Boundary Value Problems, Shooting method, Central difference method.</p> <p>Activity: solving the numerical problems using MATLAB /Micro soft office Excel.</p>					
<p>Partial Differential Equations: Finite difference solutions of elliptic equations, Liebmann's method, finite difference solutions of parabolic equations, Crank-Nicolson and implicit methods, Overview of hyperbolic equations; Case study on solving PDEs.</p> <p>Activity: solving the numerical problems using MATLAB /Micro soft office Excel.</p>					
<p>Weightage: Continuous Assessment: 40%, End Semester Examinations: 60%</p>					
<p>Assessment Methodology: Quiz (20%), Assignments (30%), Internal Examinations (50%)</p>					

References:

1. Ahuja, P. (2010). *Introduction to numerical methods in chemical engineering*. PHI Learning Pvt.
2. Chapra, S. C., & Canale, R. P. (2016). *Numerical methods for engineers*. McGraw Hill.
3. Dorfman, K. D., & Daoutidis, P. (2017). *Numerical methods with chemical engineering applications*. Cambridge University Press.
4. Jana, A. K. (2011). *Chemical process modelling and computer simulation*. Prentice Hall of India.

	Description of CO	PO	PSO1	PSO2
CO1	Explain the numerical methods required for solving chemical engineering problems	PO1(3), PO2(2)	3	2
CO2	Solve the differential equations of chemical engineering processes	PO1 (3), PO2(2), PO4(2)	2	3
CO3	Apply Interpolation & optimization methods to solve equations arising from chemical engineering processes	PO1 (3), PO2(2), PO4(2)	2	1
CO4	Apply integration & differentiation numerical methods to solve chemical processes.	PO1 (3), PO2(2), PO4(2)	2	2

CX25102	Advanced Transport Phenomena	L	T	P	C
		3	0	0	3
<p>Course Objective: To impart knowledge on the concepts of transport phenomena and flow behavior in different systems</p>					
<p>Basic Concepts: Phenomenological Equations and Transport properties, Rheological behavior of fluids, Models for Rheological Behavior; Balance Equations, Differential and Integral equations.</p> <p>Activity: Identification of rheological behaviors of different fluids.</p>					
<p>Applications of Differential Equations of Change: Applications in laminar and turbulent transport in compressible and incompressible fluids, Boundary layer theory, Momentum, Thermal and Concentration Boundary layer, Similarity Transformation, Blasius Solution.</p> <p>Activity: Writing various differential form of equation in chemical engineering.</p>					
<p>Applications of Integral Equations of Change: Reynolds Transport Theorem, application of RTT to solutions for Macroscopic balance for isothermal and non-isothermal systems and their applications in Momentum, Heat and Mass transport problems.</p> <p>Activity: List out chemical engineering application of integral equations.</p>					
<p>Interphase and Multiphase Momentum Transfer: Friction factor, Fluid Fluid systems, Flow patterns in vertical and horizontal pipes, Formulation of bubbles and drops and their size distribution, Solid fluid systems, Forces acting on stagnant and moving solids, Flow through porous medium, capillary tube model and its applications.</p> <p>Activity: Demonstration of flow through porous medium.</p>					
<p>Interphase Transport in Non-Isothermal Systems: Heat Transfer coefficient, Forced convection in tubes, around submerged objects, Heat Transfer by free convection, film type and dropwise condensation and equations for heat transfer, Heat transfer in boiling liquids, Mass Transfer co-efficient in single and multiple phases at low and high mass transfer rates, Film theory, Penetration theory, Boundary layer theory, Macroscopic balance to solve steady and Unsteady state problems.</p> <p>Activity: Seminar presentation of various non isothermal systems with industrial applications.</p>					
<p>Weightage: Continuous Assessment: 40%, End Semester Examinations: 60%</p>					
<p>Assessment Methodology: Quiz (20%), Assignments (30%), Internal Examinations (50%)</p>					
<p>References:</p> <ol style="list-style-type: none"> Bird, R. B., Lightfoot, E. N., & Stewart, E. W. (2007). Transport phenomena. Wiley. 					

2. Welty, J. R., Wicks, C. E., & Wilson, R. E. (2007). Fundamentals of momentum, heat, and mass transfer. John Wiley & Sons.
3. Deen, W. M. (1998). Analysis of transport phenomena. Topics in Chemical Engineering, Vol. 1. Oxford University Press.
4. Leal, L. G. (2007). Advanced transport phenomena: Fluid mechanics and convective transport processes (Vol. 7). Cambridge University Press.
5. Brodkey, R. S., & Hershey, H. C. (2003). Transport phenomena: A unified approach. Brodkey Publishing.

	Description of CO	PO	PSO1	PSO2
CO1:	Understand and explain phenomenological equations and rheological behavior of fluids in transport processes.	PO1(3), PO2(2)	3	2
CO2:	Apply differential equations of change to solve momentum, heat, and mass transfer problems.	PO3(1), PO2(2)	2	3
CO3:	Utilize integral equations of change for analyzing momentum, heat, and mass transport phenomena.	PO1(1), PO3(2)	2	1
CO4:	Analyze and evaluate interphase and multiphase momentum and mass transfer in both isothermal and non-isothermal systems.	PO3(3)	2	2

CX25103	Advanced Reaction Engineering	L	T	P	C
		3	0	0	3
<p>Course Objective: To teach advanced reaction engineering and apply the knowledge for the modelling & design of the chemical reactors.</p>					
<p>Gas Solid Non-Catalytic Reactions and Reactors: Reaction kinetics, Different models used for gas solid non-catalytic reactions, shrinking core model, volume reaction model, zone models, grain models, rate controlling steps; time for Complete Conversion for Single and Mixed Sizes, design of gas solid reactors.</p> <p>Activity: virtual demonstration of various models used in Gas-solid non catalytic reaction</p>					
<p>Gas Solid Catalytic Reaction: Steps in catalytic reaction, Single site, dual site mechanisms, Langmuir Hinshelwood, Eley Rideal, Rate controlling steps. Experimental methods for determining rate. Intra particle diffusion mechanism of catalytic reactions-under isothermal and non-isothermal condition.</p> <p>Activity: virtual demonstration of various Gas-solid catalytic reaction and the reactors.</p>					
<p>Fluid-Fluid Reaction: Kinetics and design of Fluid-Fluid Reactions. Rate equation, Kinetic regimes for absorption combined with chemical reaction. Various cases of mass transfer with chemical reaction, Factors to select the contactor, gas-liquid reactor design, liquid-liquid reactors and Design.</p> <p>Activity: Virtual demonstration of various kinetic regimes of fluid-fluid reactions.</p>					
<p>Advanced Reactor Systems: Conventional reactors, advanced reactors, Static mixer reactor, Monolith Reactors, Spinning disc reactor, Multifunctional Reactors, Reactive distillation, Reactive extraction, Membrane reactor; Solar reactors, Micro channel reactors.</p> <p>Activity: Virtual demonstration of various types of advanced reactor system.</p>					
<p>Modelling Of Chemical Reactor Systems: Steady state and unsteady state modelling concepts, Modelling batch reactors and tubular reactors systems, Reactor optimization.</p> <p>Activity: seminar presentation of steady state and unsteady state reactor systems.</p>					
<p>Weightage: Continuous Assessment: 40%, End Semester Examinations: 60%</p>					
<p>Assessment Methodology: Quiz (20%), Assignments (30%), Internal Examinations (50%)</p>					
<p>References:</p> <ol style="list-style-type: none"> 1. Doraiswamy, L. K., & Uner, D. (2014). <i>Chemical reaction engineering: Beyond the fundamentals</i> (1st ed.). CRC Press. 2. Froment, G. F., & Bischoff, K. B. (2011). <i>Chemical reactor design and analysis</i>. John Wiley & Sons. 3. Suresh, S., & Sundaramoorthy, S. (2014). <i>Green chemical engineering: An introduction to catalysis, kinetics, and chemical processes</i>. CRC Press. 4. Levenspiel, O. (1999). <i>Chemical reaction engineering</i>. John Wiley & Sons. 5. Fogler, H. S. (1999). <i>Elements of chemical reaction engineering</i>. Prentice Hall of India. 					

	Description of CO	PO	PSO1	PSO2
CO1:	Analyze various models and kinetics involved in non-catalytic reactions.	PO1(3), PO3(1)	3	2
CO2:	Evaluate mechanisms underlying catalytic reactions.	PO2(2), PO3(2)	2	3
CO3:	Apply principles to design fluid-fluid reactor towers.	PO1(1), PO3(2)	1	3
CO4:	Differentiate between advanced reactor systems and develop models for chemical reactors.	PO3(3)	2	2

CX25104	Advanced Process Control	L	T	P	C
		3	0	2	4
<p>Course Objective: To impart the advanced process control knowledge and apply various control systems for the industrial applications.</p>					
<p>Advanced Control Strategies: Linear, nonlinear regression fitting for first order, second order models without and with time delay; development of discrete time model and parameter identification; Advanced control, Feed forward, cascade, dead time compensation, split range, inferential, selective and override control; smith predictor; automatic tuning and gain scheduling Activity: MATLAB simulink model for first order and second order system.</p>					
<p>Model Based Control Design: Model based control, IMC structure, development and design; Direct synthesis method; IMC based PID control, Overview of MPC, prediction for SISO and MIMO models, MPC calculation, set point calculation, selecting the tuning parameters in MPC, Design examples for typical case studies; Introduction to Non-linear MPC Activity: MATLAB simulink model for PID controller and MPC.</p>					
<p>Multivariable control: Control loop interaction, general pairing problem, relative gain array and application, sensitivity; Multivariable control, zeros and performance limitations, directional sensitivity and operability, decoupling Activity: Virtual demonstration of multivariable control system</p>					
<p>Discrete systems & non-linear systems: Z – Transform and inverse Z – transform properties; Discrete, Time Response of dynamic system, Pulse Transfer Function, Closed Loop System Stability; Models for Time-varying and Nonlinear systems; Hammerstein and Wiener Systems; Fuzzy logic controls; Neural network control. Activity: Seminar presentation on Fuzzy logic controls; Neural network control</p>					
<p>Digital feedback controllers: Design of digital feedback controllers - Essential components, Digital control implementation, Programmable Logic Controller, Distributed Control System, SCADA, Hardware for computer - based control, Interfacing computer system with process. Activity: Demonstration of Interfacing computer system with process.</p>					
<p>Weightage: Continuous Assessment: 50%, End Semester Examinations: 50%</p>					
<p>Assessment Methodology: Quiz (5%), Assignments (20%), Flipped Class (5%), Practical (30%), Internal Examinations (40%)</p>					
<p>List of Experiments:</p> <ol style="list-style-type: none"> 1. Level control process with data acquisition 2. Temperature control process with data acquisition 3. Flow control process with data acquisition 4. Pressure process trainer with data acquisition 5. Implementation of Model Predictive Control in process control station 6. Implementation of Fuzzy logic, control in process control station 					

7. PLC and web based real time process control system
8. Integration of process control equipment in COMOS software
9. Create P & ID diagram
10. Simulation of process plant using COMOS software

References:

1. Bequette, B. W. (2003). Process control: Modeling, design, and simulation. Prentice Hall.
2. Stephanopoulos, G. (2015). Chemical process control. Pearson Education India.
3. Moudgalya, K. M. (2007). Digital process control. John Wiley & Sons Ltd.
4. Luyben, W. L. (2013). Process modeling, simulation & control for chemical engineers. McGraw-Hill Education.
5. Seborg, D. E., Edgar, T. F., & Mellichamp, D. A. (2013). Process dynamics and control. Wiley India.

	Description of CO	PO	PSO1	PSO2
CO1:	Identify and apply advanced control configurations to practical engineering problems.	PO1(3), PO2(2)	3	2
CO2:	Compare and evaluate the capabilities of various model-based control systems.	PO3(1), PO2(2)	2	2
CO3:	Analyze multivariable control systems, including interaction effects and sensitivity.	PO1(1), PO3(2)	2	1
CO4:	Apply Z-transform techniques for the analysis and design of discrete-time control systems.	PO3(3)	2	3

CX25105	Separation Processes	L	T	P	C
		3	0	2	4
<p>Course Objective:</p> <ul style="list-style-type: none"> To impart knowledge on recently developed unit operations like membrane separation, adsorption, Chromatography, supercritical fluid extraction and advanced distillation techniques. To acquaint the students with various types of contacting systems viz. liquid-liquid, solid-liquid, gas-solid with their technical insights. To impart knowledge on theoretical and practical insight of advanced separation techniques. To make the students understand the utilization of soft wares for the design of membrane and distillation units. To enable the students to select appropriate separation methodology for an intended application. 					
<p>Membrane Separation Processes: Membrane types, materials, synthesis and characterization; Different membrane modules; Working principle, operating parameters, membranes used, transport processes/mechanisms and industrial applications for individual membrane processes such as Reverse osmosis, nanofiltration, ultrafiltration, microfiltration; MBR; Reverse Osmosis process design using software.</p> <p>Activity: Demonstration of Reverse Osmosis process design using software.</p>					
<p>Adsorption and ION Exchange: Fundamentals and types of adsorption, Types and properties of adsorbents, Adsorption Equilibrium and isotherms, stage contact operations, Fixed bed adsorption; Ion Exchange - Fundamentals of Ion Exchange Types of Ion Exchange Resins Theory of Ion Exchange, Applications - Removal and recovery of heavy metals, Removal of nitrogen, Removal of phosphorus, Organic chemical removal.</p> <p>Activity: Industrial visit/ visit of ion exchange process units and measure the properties.</p>					
<p>Chromatographic Separation: Principle and operation, Types of chromatography - Ion exchange chromatography, Gel filtration and affinity chromatography, Thin layer and paper chromatography, Liquid chromatography, Simulated Moving bed chromatography, Multicomponent Differential Chromatography; Advantages and disadvantages of chromatographic separations.</p> <p>Activity: seminar presentation of various chromatographic separation techniques.</p>					
<p>Supercritical Extraction: Working Principal, unique properties and solubility behavior of supercritical fluids, Advantages of supercritical extraction, Decaffeination, ROSE process for purification of crude oil, hydrothermal oxidation, and Commercial applications of supercritical extraction.</p> <p>Activity: Virtual demonstration of super critical extraction process</p>					
<p>Advanced Distillation Techniques: Reactive and catalytic distillation Concept, advantage & disadvantages, Structured packing and its comparison with conventional techniques, Concept & working of short path Distillation Unit (SPDU).</p>					

Activity: Virtual demonstration of distillation process

Weightage: Continuous Assessment: 50%, End Semester Examinations: 50%

Assessment Methodology: Quiz (5%), Assignments (20%), Flipped Class (5%), Practical (30%), Internal Examinations (40%)

List of Experiments:

1. Determination of the water permeability of a given polymeric membrane.
2. Determination of permeation flux of a membrane in flat-sheet module (Dye-water solution may be used as feed) (RO/NF/UF membranes can be used)
3. Numerical/design of reverse osmosis process using software.
4. Waste Water Treatment using MBR.
5. Adsorption Equilibrium and fixed bed adsorption studies for generation of breakthrough curves
6. Determination of ion exchange capacity of a given cation or anion exchanger
7. To separate a mixture of dyes using chromatography
8. Experimental design in supercritical fluid extraction
9. Study of extraction efficiency for the extraction of essential oils
10. Numerical/design assignment based on reactive and catalytic distillation.

References:

1. Seader, J. D., & Henley, E. J. (1998). Separation process principles. John Wiley & Sons.
2. Dutta, B. K. (2006). Principles of mass transfer and separation processes. Prentice Hall India Learning Private Limited.
3. Baker, R. W. (2012). Membrane technology and applications. John Wiley & Sons.
4. Geankoplis, C. J. (2004). Transport processes and separation process principles. Prentice Hall India Learning Private Limited.
5. Wankat, P. C. (2006). Separation process engineering. Pearson Education.

	Description of CO	PO	PSO1	PSO2
CO1:	Design and develop membrane systems to determine flux and separation efficiency.	PO1(3), PO2(2)	2	3
CO2:	Analyse fixed bed column operations such as adsorption and ion exchange for fluid component separation.	PO3(1), PO2(2)	3	1
CO3:	Apply chromatographic techniques for effective separation and analysis of mixtures.	PO1(1), PO3(2)	3	2
CO4:	Interpret phase diagrams and optimize supercritical fluid and advanced distillation processes.	PO3(3)	2	2

SEMESTER II

Course Objectives:

This course will enable the students:

- To understand the concept of Process Intensification.
- To provide knowledge and understanding of application of intensification techniques to a range of processes like heat and mass transfer, separation processes.
- To provide an understanding of basic operating principles of a variety of intensified process equipment such as spinning disc reactor, rotary packed beds, oscillatory flow reactors, compact heat exchangers and micro-reactors etc.

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.

Novel Reactors: Introduction to spinning disc reactor, Rotor stator reactors: the STT reactor, Taylor– Couette reactor, Rotating packed-bed reactors, Oscillatory baffled reactors (OBRs), Micro-reactors (The catalytic plate reactor (CPR), HEX-reactors), Hydrodynamic Cavitation Reactors

Intensive mixers: Introduction to special types of mixers, Ultrasound mixers, 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.

Combined chemical reactor heat exchangers and reactor separators: Principles of operation; Applications, Reactive absorption, Reactive distillation, Reactive Extraction Case Studies: 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.

Enhanced fields: Energy based intensifications, Sono-chemistry, Basics of cavitation, Cavitation Reactors, Nusselt-flow model and mass transfer, The Rotating Electrolytic Cell, Microwaves, Electrostatic fields, Sono-crystallization, Supercritical fluids.

REFERENCE BOOKS:

1. Segovia-Hernández, A. and Moulijn, (Eds.), Reengineering the Chemical Process Plants, Process Intensification, Marcel Dekker, 2003.
2. Reay D., Ramshaw C., Harvey A., Process Intensification, Butterworth Heinemann, 2008.
3. Kamelia Boodhoo (Editor), Adam Harvey (Editor), Process Intensification Technologies for Green Chemistry: Engineering Solutions for Sustainable Chemical Processing, Wiley, 2013.
4. z, Juan Gabriel, Bonilla-Petriciolet, Adrián (Eds.) Process Intensification in Chemical Engineering Design Optimization and Control, Springer, 2016.
5. Reay, Ramshaw, Harvey, Process Intensification, Engineering for Efficiency, Sustainability and Flexibility, Butterworth-Heinemann, 2013.

Course Evaluation:

Individual assignment, Theory (Quiz and End semester) examinations

CX25202	Modeling of Chemical Processes	L	T	P	C
		3	1	0	4
<p>Course Objective: Impart fundamental and advanced knowledge of chemical process modelling and to enable application of numerical, computational, and data-driven techniques.</p>					
<p>Overview: Need for developing models for a process - Incentives of process modeling and simulation - classification of mathematical models, conservation equations and auxiliary relations - Closed form of solution – Well posedness of Models, Degree of freedom analysis - Design and Control degrees of Freedom - Degrees of Freedom Analysis for flowsheets involving single and multiple process units.</p> <p>Activity: Solving the numerical problems using MATLAB/ASPEN Plus</p>					
<p>Algebraic Models: Models yielding linear and non-linear algebraic equations - Solution to linear and non-linear algebraic equations - Convergence - Types of Convergence - Wegstein's Algorithm - Levenberg-Marquadt Method, Application of algebraic models to dimensional analysis and determination of independent species in a set of reactions.</p> <p>Activity: Solving the numerical problems using MATLAB /ASPEN Plus</p>					
<p>Models Yielding Ode: Models yielding ODE - Classification of ODE - Solution of ODE - analytical methods using matrices and numerical methods, Runge- Kutta methods of various orders, Mathematical models with Initial and or Boundary conditions of surge tank, Transient isothermal and non-isothermal Mixed flow reactor, Separation systems such as distillation and flashing.</p> <p>Activity: solving the numerical problems using MATLAB /ASPEN Plus</p>					
<p>Models Yielding Pde: Models yielding PDE's - Characteristics and differences between Lumped and Distributed Parameter systems - classification and solution of partial differential equations - Mathematical models of Heat Exchanger, Packed bed reactor, plug flow reactor, Convection-Diffusion-Reaction (CDR) model, packed bed adsorption, Solution of ODE boundary value problems.</p> <p>Activity: solving the numerical problems using MATLAB / ASPEN Plus</p>					
<p>Other Models and Softwares: Empirical modeling, parameter estimation, Principal Component Analysis - Kernel PCA - Solve the problems using MATLAB/SCILAB and ASPEN Plus, Machine learning or Deep Learning Model Development, Artificial Neural Networks.</p> <p>Activity: solving the numerical problems using MATLAB / ASPEN Plus</p>					
<p>Weightage: Continuous Assessment: 40%, End Semester Examinations: 60%</p>					
<p>Assessment Methodology: Quiz (20%), Assignments (30%), Internal Examinations (50%)</p>					

REFERENCES:

1. Bequette, B.W., "Process Dynamics: Modelling, Analysis and Simulation," Prentice Hall (1998).
2. Himmelblau D.M. and Bischoff K.B., Process Analysis and Simulation, Wiley, 1988.
3. Varma A. and Morbidelli M., Mathematical Methods in Chemical Engineering, Oxford University Press, 1997.
4. Gilbert Strang, "Linear Algebra and its Applications", Wellesley, MA : Wellesley-Cambridge Press, Fourth Edition, 2009.
5. Ogunnaike B. and W. Harmon Ray, Process Dynamics, Modeling, and Control, Oxford University Press, 1995.
6. Chapra S.C. and Canale R.P. Numerical Methods for Engineers, McGraw Hill, 2001.
7. Ramirez, W.; " Computational Methods in Process Simulation ", 2nd Edn., Butterworths Publishers, New York, 2000.

	Description of CO	PO	PSO1	PSO2
CO1	Analyze chemical process systems using fundamental modeling principles	PO1(3), PO2(2)	3	2
CO2	Formulate and solve algebraic and ordinary differential equation–based models	PO1 (3), PO2(2), PO3(2)	2	3
CO3	Develop and analyze distributed parameter models using partial differential equations	PO1 (3), PO2(2), PO3(2)	2	1
CO4	Apply computational and data-driven modeling tools	PO1 (3), PO2(2), PO3(2)	2	2

CX25203 Advanced Thermodynamics for Chemical Engineers**L T P C**
3 0 0 3**OBJECTIVES:**

- To impart knowledge on the basics of laws of energy relations and partial derivatives for PVT relations
- To enable the students to understand the thermodynamics of phase equilibria typically present in design of chemical processes, in particular, in separation operations
- To impart the students to learn about advance Phase and chemical equilibria of multi-component systems
- To enable the students to learn about molecular thermodynamics to understand the multi-component interactions
- To make the students to relate thermodynamic concepts to separation applications, specifically related to petroleum and chemical process industries.

Overview of Thermodynamics

Thermodynamic Energy Law; Reversibility and second Law; Review of Basic Postulates, equation of state and its applications, corresponding states, equilibrium criteria, Entropy calculations, Maxwell's relations.

Fluid Phase Equilibria

Phase rule, Stability of thermodynamic systems, first order phase transitions and critical phenomenon, single component phase diagrams, thermodynamic properties of single phase and multicomponent system.

Solution Thermodynamics

Partial molar properties, Gibbs-Duhem equation, fugacities in gas and liquid mixtures, activity coefficients, Ideal and Non-ideal solutions, azeotropes, Excess Functions; Calculation of vapor liquid equilibria using equations of state; Classical and excess free energy based mixing rules, Wilson, NRTL, and UNIQUAC equations, UNIFAC method.

Vapor Liquid Equilibria

Vapour Liquid Equilibrium involving low pressure, high pressures and multi component systems, VLE in ideal and non-ideal solutions, Solid-Liquid Equilibria (SLE); Vapor-Liquid Liquid Equilibria(VLLE);Phase Equilibria of Solid-Solid Mixtures. Applications - Phase equilibria in polymer solutions, Electrolytes

Reaction Equilibria

Criteria of chemical reaction equilibrium in thermodynamic systems, Homogeneous gas and liquid phase reactions, heterogeneous reactions – phase and chemical equilibrium, Introduction to molecular thermodynamics, Intermolecular forces, Potential function

Course Outcomes:

- CO1: Recall the basic concepts of energy and laws of thermodynamics to applications that require quantitative knowledge of thermodynamic properties at macroscopic level.
- CO2: Review the thermodynamics of phase equilibria for the design of chemical processes
- CO3: Analyze the fundamental property relation and derivative relations and compute the VLE using excess energy models
- CO4: Apply the solution methods for vapor -liquid equilibrium and understand the LLE and VLLE phase behavior, including the ability to identify the onset of liquid instability
- CO5: Assess the influences of pressure, nonstoichiometric feed and inerts on reaction equilibrium and the Gibbs minimization method for calculating reaction equilibrium.

References:

1. J. Richard Elliott, Carl T. Lira, a Introductory Chemical Engineering Thermodynamics, 2nd Edition", 2nd edition, Prentice Hall, 2012
2. J.M.Smith, H.C.Van Ness, Michael M. Abbott, Introduction to Engineering Thermodynamics, McGraw Hill, New York, 2005.
3. M.D. Koretsky, Engineering and Chemical Thermodynamics, 2nd edition, Wiley; 2nd edition, 2012
4. Prauznitz, J.M., R.N. Lichtenthaler, E.G. de Azevedo, "Molecular Thermodynamics of Fluid Phase Equilibria", 3rd ed., Prentice Hall, 1999
5. S.M. Walas, Phase Equilibria in Chemical Engineering•, Butterworths, 1985.
6. Y.V.C.Rao, Chemical Engineering Thermodynamics, 2003

Course Articulation Matrix:

Course Outcomes	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	Recall the basic concepts of energy and laws of thermodynamics to applications that require quantitative knowledge of thermodynamic properties at macroscopic level.	3	3	3	3	3	1
CO2	Review the thermodynamics of phase equilibria for the design of chemical processes	3	3	3	3	3	1
CO3	Analyze the fundamental property relation and derivative relations and compute the VLE using excess energy models	3	3	3	3	3	2
CO4	Apply the solution methods for vapor -liquid equilibrium and understand the LLE and VLLE phase behavior, including the ability to identify the onset of liquid instability	2	3	3	3	3	2
CO5	Assess the influences of pressure, nonstoichiometric feed and inerts on reaction equilibrium and the Gibbs minimization method for calculating reaction equilibrium.	3	3	3	3	3	2
Average CO		2.8	3	3	3	3	1.6

1, 2 and 3 are correlation levels with weightings as Slight (Low), Moderate (Medium) and Substantial (High) respectively

OBJECTIVES:

- To enable the students to learn basics of Optimization.
- To enable the students to learn Formulation of an optimization problem
- To impart knowledge on finding solutions for nonlinear unconstrained optimization.
- To enable the students to understand the role of constraints on the solution of an optimization problem
- To make the students to explore the optimal and dynamic optimization techniques.

Introduction

Introduction to optimization; applications of optimization in chemical engineering; classification of optimization problems; Problem formulation, degree of freedom analysis, objectives functions, constraints and feasible region, general procedure for solving optimization problems, Types of optimization problem, obstacles to optimization.

Linear Programming

Introduction to Linear Programming (LP). Graphical representation. Basic assumptions. Simplex method, Barrier method, sensitivity analysis, Examples.

Nonlinear Unconstrained Optimization

Convex and concave functions unconstrained NLP, Newton's method Quasi-Newton's method, Examples.

Constrained Optimization

Direct substitution, Quadratic programming, Penalty Barrier Augmented Lagrangian Methods.

Multi Objectives Optimization

Weighted Sum of Squares method, Epsilon constrain method, Goal attainment, Examples.

Introduction to optimal control and dynamic optimization.

Course Outcomes:

- CO1: Describe the basics problem formulation and optimization.
- CO2: Discuss mathematical characteristics of linear programming.
- CO3: Explain computational solution techniques for nonlinear unconstrained optimization.
- CO4: Demonstrate various techniques used in constrained optimization
- CO5: Apply the optimal and dynamic optimization.

References:

1. Edgar, T. F., Himmelblau, D. M. and Ladson, L. S., "Optimization of Chemical Processes", 2nd Ed., McGraw Hill, New York, 2003.
2. Rao, S. S., Engineering Optimization: Theory and Practice, New Age Publishers, 2000
3. Diwaker, U. W. "Introduction to Applied Optimization", Kluwer, 2003.
4. Joshi, M. C. and Moudgalya, K. M., "Optimization, Theory and Practice", Narosa, New Delhi, 2004.

COURSE ARTICULATION MATRIX:

Course Outcomes	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	Describe the basics problem formulation and optimization.	3	1	2	3	3	2
CO2	Discuss mathematical characteristics of linear programming.	3	1	2	3	3	-
CO3	Explain computational solution techniques for nonlinear unconstrained optimization.	3	1	2	3	3	2
CO4	Demonstrate various techniques used in constrained optimization	3	1	2	3	3	1
CO5	Apply the optimal and dynamic optimization.	3	1	2	3	3	1
Average CO		3	1	2	3	3	1.2

1, 2 and 3 are correlation levels with weightings as Slight (Low), Moderate (Medium) and Substantial (High) respectively

Course Objectives:

To understand fundamental chemical engineering principles through virtual experiments

List of suggested virtual lab expedients:

1. Virtual lab experiment for advanced oxidation process experiments
2. Virtual lab experiments for simulation of simple chemical engineering process using MATLAB- Simulink simulations
3. Simulation of simple unit operation and unit process using a chemical engineering process simulator
4. Develop a simple one dimensional flow modelling using computational dynamic software tool.
5. Simulation lab to do the start-up and shutdown of chemical process plant.
6. Integration of process control equipment in COMOS software
7. Simulation of process plant using COMOS software

COURSE OUTCOMES:

- CO1 Simulate chemical engineering experiments using virtual lab software
- CO2 Interpret the experimental data and prepare lab reports
- CO3 Relate theoretical concepts to real-world chemical processes
- CO4 Understand safety, process control, and operational parameters
- CO5 Visualize the simulation of chemical process plant start-up and shutdown

References:

1. Luyben, W. L. (2013). Process modeling, simulation & control for chemical engineers. McGraw-Hill Education
2. Ramirez, W.; "Computational Methods in Process Simulation ", 2nd Edn., Butterworths Publishers, New York, 2000.

SEMESTER III

CX25301

Project Work – I

L T P C
0 0 12 6

OBJECTIVES:

- To enable the students to identify a specific problem related to Chemical Engineering and carrying out a detailed literature review.

- To make the students to Conduct experiments/study in detail to find suitable solution for the problem.
- To impart the students in preparing project reports, to present their findings in reviews and viva-voce examination.

Course Content:

The student individually works on a specific topic selected by him/her which is relevant to his/her specialization of the programme approved by a faculty member who is familiar in the particular area of interest. The topic may be experimental or analytical or case studies. At the end of the semester, a detailed report on the work done should be submitted which contains a clear definition of the identified problem, detailed literature review related to the area of work and methodology for carrying out the work. The students will be evaluated through reviews internally by panel members and a final viva-voce examination conducted at the end of the semester by a panel of one internal and one external examiner.

Course Outcomes:

CO1: Identify project goals, constraints, deliverables, performance criteria, control needs, and resource requirements.

CO2: Interact with team in a professional manner to ensure a collaborative project environment.

CO3: Ability to express clearly the findings and relate to theoretical background.

Course Articulation Matrix:

Course Outcomes	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	Identify project goals, constraints, deliverables, performance criteria, control needs, and resource requirements.	3	3	3	3	3	3
CO2	Interact with team in a professional manner to ensure a collaborative project environment.	3	3	3	3	3	3
CO3	Ability to express clearly the findings and relate to theoretical background.	3	3	3	3	3	3
Average CO		3	3	3	3	3	3

1, 2 and 3 are correlation levels with weightings as Slight (Low), Moderate (Medium) and Substantial (High) respectively

SEMESTER IV

CX25401

Project Work - II

L T P C
0 0 24 12

OBJECTIVES:

- To enable the students to execute the proposed procedure in solving the identified problem.
- To make the students develop skills to analyze and discuss the results obtained and make conclusions.
- To impart the students to relate the experimental data with the real time process

COURSE CONTENT:

The student individually works on a specific topic selected by him/her which is relevant to his/her specialization of the programme approved by a faculty member who is familiar in the particular area of interest. The topic may be experimental or analytical or case studies. At the end of the semester, a detailed report on the work done should be submitted which contains a clear definition of the identified problem, detailed literature review related to the area of work and methodology for carrying out the work. The students will be evaluated through reviews internally by panel members and a final viva-voce examination conducted at the end of the semester by a panel of one internal and one external examiner.

COURSE OUTCOMES:

CO1: Utilize technology and software tools for support.

CO2: Relate the findings to existing systems that they prioritize novel outcomes and publish in Indian/International Journals, proceedings and patents proposal

CO3: Create their ideas, interpret the data acquired and defend their research work to a panel of experts

Course Articulation Matrix:

Course Outcomes	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	Utilize technology and software tools for support.	3	3	3	3	3	3
CO2	Relate the findings to existing systems that they prioritize novel outcomes and publish in Indian/International Journals, proceedings and patents proposal	3	3	3	3	3	3
CO3	Create their ideas, interpret the data acquired and defend their research work to a panel of experts	3	3	3	3	3	3
Average CO		3	3	3	3	3	3

1, 2 and 3 are correlation levels with weightings as Slight (Low), Moderate (Medium) and Substantial (High) respectively

Objectives

- To enable the students to learn the fundamentals of sustainability in the context of engineering.
- To enable the students to analyze the environmental impact of chemical processes and identify opportunities for improvement.
- To impart knowledge on sustainable process design and optimization techniques.
- To enable the students to evaluate energy efficiency and resource conservation strategies in industries/ plants.
- To enable the students to develop skills for implementing sustainable practices in engineering projects and operations.

Introduction to Sustainable Management

Overview of sustainability principles and their relevance to chemical/petroleum/environmental engineering; Environmental challenges in the chemical industry; Introduction to sustainable development goals and their application in chemical engineering; Role of engineers in promoting sustainability; Introduction to life cycle assessment (LCA) and environmental impact analysis.

Sustainable Process Design and Optimization

Principles and strategies for sustainable process design, Analysis and optimization of chemical processes for sustainability; Integration of green chemistry principles in process design; Case studies on sustainable process design in chemical engineering; Tools and software for sustainable process design and optimization.

Energy Efficiency and Conservation

Energy consumption and environmental impact of chemical processes; Strategies for improving energy efficiency in chemical plants; Energy conservation techniques in heat transfer, separation processes, and reactions; Integration of renewable energy sources in chemical processes; Case studies on energy-efficient operations in chemical engineering.

Waste Minimization and Resource Recovery

Waste generation in chemical processes and its impact on the environment; Techniques for waste minimization and treatment; Resource recovery from waste streams, Recycling and circular economy principles in chemical engineering; Case studies on waste reduction and resource recovery in chemical processes.

Sustainable Supply Chain Management in Industry

Sustainability considerations in the chemical supply chain; Responsible sourcing of raw materials, Green packaging and logistics practices; Supplier assessment and management for sustainability; Certification systems and standards for sustainable supply chains.

Course Outcomes:

- CO1: Identify and discuss the key principles and concepts of sustainability in the context of engineering.
- CO2: Analyze and evaluate the environmental impact of chemical processes and propose sustainable solutions.
- CO3: Design and optimize chemical processes considering sustainability factors and green chemistry principles.

CO4: Assess and implement energy-efficient strategies and resource conservation techniques in chemical plants.

CO5: Apply sustainable supply chain management principles to ensure responsible sourcing and minimize environmental impact.

References:

1. Beder, Sharon., "Environmental principles and policies: an interdisciplinary introduction", Routledge, 2013.
2. Elkington, John, and Ian H. Rowlands. "Cannibals with forks: The triple bottom line of 21st century business." *Alternatives Journal* 25, no. 4,42, 1999.
3. Fiksel, Joseph. *Design for environment: a guide to sustainable product development*. McGraw-Hill Education, 2009.
4. Johansson, Allan. *Clean technology*. CRC Press, 1992.
5. Kane, Gareth. *The green executive: corporate leadership in a low carbon economy*. Routledge, 2012.
6. Kirkwood, Ralph, and Anite Longley, eds. *Clean technology and the environment*. Springer Science & Business Media, 1994.
7. Mulder, Karel, ed. *Sustainable development for engineers: A handbook and resource guide*. Routledge, 2017.
8. Marinova, Dora, David Annandale, and John Phillimore, eds. *The international handbook on environmental technology management*. Edward Elgar Publishing, 2008.
9. Von Weizsäcker, Ernst Ulrich, Amory B. Lovins, and L. Hunter Lovins. *Factor four: doubling wealth—halving resource use: a new report to the club of Rome*. Springer International Publishing, 2014.
10. Willums, Jan-Olaf. *The sustainable business challenge: a briefing for tomorrow's business leaders*. Routledge, 1998.
11. Harmsen, Jan, and Joseph B. Powell. *Sustainable development in the process industries*. Hoboken, NJ: John Wiley & Sons, 2010.

Course Articulation Matrix:

Course Outcomes	Statement	Program Outcomes					
		PO1	PO2	PO3	PO4	PO5	PO6
CO1	Identify and discuss the key principles and concepts of sustainability in the context of engineering	3	3	3	1	1	1
CO2	Analyze and evaluate the environmental impact of chemical processes and propose sustainable solutions	1	2	2	3	3	2
CO3	Design and optimize chemical processes considering sustainability factors and green chemistry principles	2	3	3	3	3	2
CO4	Assess and implement energy-efficient strategies and resource conservation techniques in chemical plants	2	2	1	3	1	1
CO5	Apply sustainable supply chain management principles to ensure responsible sourcing and minimize environmental impact	1	2	2	2	3	2
Average CO		1.80	2.40	2.20	2.40	2.20	1.60

1, 2 and 3 are correlation levels with weightings as Slight (Low), Moderate (Medium) and Substantial (High) respectively.

Objectives:

- To impart knowledge on sampling and sampling distribution and to apply hypothesis testing with different confidence intervals
- To enable the students, develop skills in linear regression, both univariate and multivariate, and utilize least squares methods to estimate and interpret regression models.
- To enable the students to interpret experimental results using ANOVA, report data, and construct confidence intervals.
- To enable the students to perform ANOVA and regression analysis
- To enable the students to explore variable selection, fractional factorial design, and robustness in experimental design.

Foundations of Probability and Statistics for Engineers

Introduction to probability and statistics - including concepts and principles; Statistical inference fundamentals - such as estimation and hypothesis testing; Confidence intervals - providing a range of plausible values for population parameters; Hypothesis tests to make decisions based on experimental data.

Principles of Experimental Design

Statistical principles in experimental design - including the control of sources of variation; Blocking and complete randomization techniques; Factorial design to study the effects of multiple factors on the response variable; Analysis of individual factor effects and interaction effects; Introduction to response surface methodologies for optimizing response variables within a design space.

Regression Modeling and Analysis

Linear regression techniques - both univariate and multivariate - to model relationships between variables; Least Squares estimation - including its basic principles and variants; Nonlinear regression methods to model non-linear relationships; Techniques for model assessment, interpretation, and evaluation of regression models.

Analysis of Variance and Experimental Inference

Introduction to ANOVA - a statistical technique for comparing means among multiple groups or treatments; Interpretation of results from experiments using ANOVA; Effective reporting of experimental data; Construction of confidence intervals to estimate population means and differences.

Advanced Topics in Statistics and Experimental Design

Exploration of additional topics in statistics and experimental design; Variable selection techniques to identify significant factors in regression models; Fractional factorial design for efficient exploration of factor combinations; Robustness in experimental design and analysis - focusing on the stability and reliability of statistical methods in the presence of deviations from assumptions.

List of tasks to be performed by students: Software Minitab

- 1) Exploratory Data Analysis:** Import a dataset into Minitab and perform exploratory data analysis; Calculate descriptive statistics - such as mean, median, and standard deviation; Create graphical representations of the data, including histograms, box plots, and scatter plots.
- 2) Probability Distribution Analysis:** Generate random numbers from different probability distributions in Minitab - such as normal, exponential, or binomial; Fit probability distributions to data and assess goodness-of-fit using Minitab's distribution fitting tools.
- 3) Hypothesis Testing and Confidence Intervals:** Formulate hypotheses and perform hypothesis tests using Minitab for various scenarios; Conduct t-tests, chi-square tests, or ANOVA tests to compare population means or proportions.
- 4) Experimental Design and Analysis:** Design and execute experiments using Minitab's design of experiments (DOE) tools; Analyze the results of designed experiments - including factorial designs, using Minitab's DOE analysis features; Assess the significance of factor effects and interaction effects.
- 5) Regression Modeling and Analysis:** Perform linear regression analysis in Minitab to model relationships between variables; Interpret the coefficients and significance of predictors in regression models; Assess the goodness-of-fit and validity of regression models using diagnostic plots and statistical tests in Minitab.

Course Outcomes:

- CO1: Recognize and recall foundational probability and statistics concepts and apply them to solve engineering problems.
- CO2: Apply statistical inference techniques to draw conclusions from experimental data.
- CO3: Analyze variance (ANOVA) technique and apply it to experimental design and interpretation of results.
- CO4: Illustrate skills in linear regression modeling and interpret regression models for engineering applications.
- CO5: Apply statistical principles to experimental design and assess model adequacy for regression models.

Practical

- CO1: Recall and apply foundational statistical concepts in practical data analysis using software tools like Minitab.
- CO2: Demonstrate proficiency in conducting hypothesis tests, constructing confidence intervals, and analyzing experimental data using software.
- CO3: Analyze regression models, interpret their coefficients, and evaluate model adequacy through diagnostic plots and statistical tests using software.

References:

1. R.L. Mason, R.F. Gunst and J.L. Hess (2005). Statistical Design and Analysis of Experiments – with applications to engineering and science, 2 nd edition, John Wiley & Sons
2. Design of Experiments in Chemical Engineering: A Practical Guide by Z. R. Lazic, John Wiley

3. R.A. Johnson, I. Miller and J. Freund (2007). Probability and Statistics for Engineers, 7 th edition, Prentice Hall Inc.
4. D.C. Montgomery and G.C. Runger (2007). Applied Statistics and Probability for Engineers, 4th edition, John Wiley & Sons Inc.
5. Box, George EP, J. Stuart Hunter, and William G. Hunter. "Statistics for experimenters." In Wiley series in probability and statistics. Hoboken, NJ: Wiley, 2005.

Course Articulation Matrix:

Course Outcomes	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	Recognize and recall the fundamental concepts of probability and statistics and apply them to engineering problems.	3	1	3	1	1	1
CO2	Apply statistical inference techniques to draw conclusions from experimental data.	1	3	1	1	3	1
CO3	Analyze variance (ANOVA) technique and apply it to experimental design and interpretation of results	1	1	3	1	1	1
CO4	Illustrate skills in linear regression modeling and interpret regression models for engineering applications	2	1	3	1	1	1
CO5	Apply statistical principles to experimental design and assess model adequacy for regression models.	1	1	1	1	3	1
Practical							
CO1	Recall and apply foundational statistical concepts in practical data analysis using software tools like Minitab.	1	1	2	2	3	2
CO2	Demonstrate proficiency in conducting hypothesis tests, constructing confidence intervals, and analyzing experimental data using software.	3	2	2	2	3	2
CO3	Analyze regression models, interpret their coefficients, and evaluate model adequacy through diagnostic plots and statistical tests using software.	2	1	1	2	3	2
Average CO		1.80	1.40	2.00	1.40	2.30	1.40

1, 2 and 3 are correlation levels with weightings as Slight (Low), Moderate (Medium) and Substantial (High) respectively

Objectives:

- To enable the students to understand importance and measuring methods of various measurement parameters.
- To enable the students to understand and apply suitable instruments for measuring temperature, humidity and others.
- To enable the students to apply suitable analytical instruments for analyzing different samples.
- To enable the students to understand the necessity of controllers and sensors in measuring devices.
- To enable the students to analyze the industrial application and positioning of the measuring instruments.

Introduction

Introduction – Variables, Units & standards of measurement, Measurement terms – characteristic. Data Analysis - why are the measurements of these parameters important in industry? Different methods for measurement of motion parameters: Displacement, velocity, acceleration, vibration, torque, force etc. Measurement of straightness, flatness, roundness and roughness.

Typical case study/design example: Instrumentation system for motion measurement in industry.

Measuring Instruments

Process Variables Measurement–Temperature systems– Thermocouples, Thermo resistive system, Filled-system thermometers, Radiation thermometry, Location of temperature measuring devices in equipments, Pressure system – Mechanical pressure elements Pressure Transducers and Transmitters, Vacuum measurement, Resonant wire pressure Transducer, Flow system – Differential producers, Variable area flow meters, Velocity, vortex, mass, ultrasonic & other flow meters, positive displacement flow meters, Open – channel flow measurements, Force systems, Strain gauges Humidity Moisture system, Humidity Measurement, Moisture measurement system, Rheological system, Viscosity measurement, Radiation system, Nuclear radiation instrumentation.

Analytical Instruments

Analytical instrumentation – Analysis instruments, Sample conditioning for process analyzers, X-ray Analytical methods, Quadrupole mass spectrometry, Ultra violet Absorption Analysis, Infra-red process analyzers, Photometric reaction product analyzers, Oxygen analyzers, Oxidation – reduction potential measurements, pH measuring systems, Electrical conductivity and Resistivity measurements, Thermal conductivity, gas analysis, Combustible, Total hydro carbon, and CO analyzer, Chromatography

Controllers and Sensors

Fundamentals of Automatic process control – Control algorithms-Automatic controllers – Electronic controllers -Electric controllers (Traditional) - Hydraulic controllers – Fluidics - Programmable controllers. Sensors, Transmitters and control valves - Pressure, Flow, Level, Temperature and Composition sensors, Transmitters, Pneumatic and electronic control valves, Types, Actuator, accessories, Instrumentation symbols and Labels.

Industrial Safety and Specifications

Safety: Introduction, electrical hazards, hazardous areas and classification, Non-hazardous areas. Enclosures – NEMA types, fuses and circuit breakers, protection methods: purging, explosion proofing and intrinsic safety. Specification of instruments, preparation of project documentation, process flow sheet, Instrument index sheet, Instrument specification sheet, panel drawing and specifications.

Course outcomes:

- CO1 List different process variables and their measurement units.
- CO2 Recognize and recall the principle and working of various process variable measuring instruments.
- CO3 Describe the principle, working and range of various analytical instruments.
- CO4 Explain the role of controllers and sensors in industrial instrumentation.
- CO5 Rate the need of safety and specifications in Industries.

References:

1. R.K.Jain, "Mechanical and Industrial Measurements", Khanna Publishers, New Delhi.
2. C. D. Johnson, "Process Control Instrumentation Technology", PHI.
3. S.K. Singh, "Industrial Instrumentation and Control", Tata McGraw Hill Publishing Ltd., New Delhi.
4. Measurement Systems, Ernest O Doebelin & Dhanesh N Manik, McGraw Hill Education; 6 edition (July 2017).
5. Principles of Industrial Instrumentation, D Patranabis, McGraw Hill Education; 3 edition (July 2017).
6. A Course in Electronic Measurements and Instrumentation, A.K. Sawhney, Dhanpat Rai & Co. (P) Limited (2015).
7. Instrumentation, Measurement and Analysis, B. C. Nakra and K. K. Chaudhary, McGraw Hill Education India Private Limited; Fourth edition (1 August 2016).

Course Articulation Matrix:

Course Outcomes	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	List different process variables and their measurement units.	3	3	3	1	2	2
CO2	Recognize and recall the principle and working of various process variable measuring instruments.	3	3	3	1	2	2
CO3	Describe the principle, working and range of various analytical instruments.	3	3	3	1	2	2
CO4	Explain the role of controllers and sensors in industrial instrumentation.	3	3	3	1	2	2
CO5	Rate the need of safety and specifications in Industries.	3	3	3	1	2	2
Overall CO		3	3	3	1	2	2

1, 2 and 3 are correlation levels with weightings as Slight (Low), Moderate (Medium) and Substantial (High) respectively

Objectives:

- To impart knowledge on the role of enzymes and microbes in biotechnology sectors.
- To enable students to understand the design parameters in designing biochemical reactors.
- To impart knowledge on finding solutions to the problems with biomaterials and processes
- To impart knowledge in bioreactors
- To enable students to study economy of bio based industries.

Enzyme Catalysis

Overview of biotechnology, Principles of Enzyme catalysis, Enzyme inhibition, Immobilized enzyme kinetics, internal mass transfer effects in immobilized enzyme kinetics.

Microbial Growth

Stoichiometry and energetics of microbial growth, Metabolic pathways and energetics of the cell, concept of energy coupling, ATP and NAD, Unstructured models of microbial growth, Structured models of microbial growth.

Bioreactor Design and Analysis

Bioreactors: CSTR, Plug flow and packed bed bioreactors, Fed batch reactors, Mass balances for two phase reactors, Power requirements, sterilization.

Product Recovery

Bioproduct recovery- Centrifugation, Filtration, Ultra filtration, Precipitation of Protein, Chromatography, Fixed bed adsorption, Phase theory of chromatography, Electrophoresis, Crystallization.

Bioproducts and Economics

Manufacturing of biological products, cost analysis of bioprocesses, case studies.

Course Outcomes:

- CO1: Develop the ability to design novel bioprocesses for their research.
CO2: Classify engineering aspects of biological systems
CO3: Develop solutions to the problems with biomaterials and processes
CO4: Apply knowledge in bioreactors
CO5: Analyze economy of bio based industries.

References:

1. Shuler M.L. and Kargi F. Bioprocess Engineering: Basic Concepts, 1st Edition, Prentice Hall, New Jersey, 1992.
2. Lee J., Biochemical Engineering, Prentice Hall Englewood Cliffs, 1992.
3. Blanch H.W and Clark D.S, Biochemical Engineering, Marcel Dekker 1997.
5. James M.Lee , Biochemical engineering – Prentice-Hall-1992.
4. Shigeo Katoh, Jun-ichi Horiuchi and Fumitake Yoshida, "Biochemical Engineering", Wiley, 2015.
5. Pauline M. Doran, Bioprocess engineering principles, Academic Press.
6. H.W. Blanch and D.S. Clark, Marcel Dekker, Biochemical Engineering, 1997

Course Articulation Matrix:

Course Outcomes	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	Develop the ability to design novel bioprocesses for their research.	1	2	1	-	-	1
CO2	Classify engineering aspects of biological systems	1	1	2	-	2	3
CO3	Develop solutions to the problems with biomaterials and processes	1	2	2	-	2	3
CO4	Apply knowledge in bioreactors	1	3	3	1	2	1
CO5	Analyze economy of bio based industries.	1	2	3	1	2	3
Average CO		1	2	3	2	1	2

1, 2 and 3 are correlation levels with weightings as Slight (Low), Moderate (Medium) and Substantial (High) respectively

Objectives:

- To enable the students to interpret the various types of wastes from which energy can be generated
- To impart knowledge on biomass pyrolysis process and its applications
- To impart knowledge on various types of biomass gasifiers and their operations
- To impart knowledge on biomass combustors and its applications on generating energy
- To enable the students to summarize the principles of bio-energy systems and their features

Introduction to Extraction Of Energy From Waste

Classification of waste as fuel – Agro based, Forest residue, Industrial waste - MSW – Conversion devices – Incinerators, gasifiers, digestors.

Pyrolysis

Pyrolysis – Types, slow fast – Manufacture of charcoal – Methods - Yields and application – Manufacture of pyrolytic oils and gases, yields and applications.

Gasification

Gasifiers – Fixed bed system – Downdraft and updraft gasifiers – Fluidized bed gasifiers – Design, construction and operation – Gasifier burner arrangement for thermal heating – Gasifier engine arrangement and electrical power – Equilibrium and kinetic consideration in gasifier operation.

Combustion

Biomass stoves – Improved chullahs, types, some exotic designs, Fixed bed combustors, Types, inclined grate combustors, Fluidized bed combustors, Design, construction and operation - Operation of all the above biomass combustors.

Bio Energy

Properties of biogas (Calorific value and composition), Biogas plant technology and status - Bio energy system - Design and constructional features - Biomass resources and their classification - Biomass conversion processes - Thermo chemical conversion - Direct combustion - biomass gasification - pyrolysis and liquefaction - biochemical conversion - anaerobic digestion - Types of biogas Plants – Applications - Alcohol production from biomass - Bio diesel production -Urban waste to energy conversion - Biomass energy programme in India.

Course Outcomes:

- CO1: Identify various types of wastes from which energy can be generated
CO2: Describe biomass pyrolysis process and its applications
CO3: Appraise various types of biomass gasifiers and their operations
CO4: Evaluate biomass combustors and its applications on generating energy
CO5: Assess the principles of bio-energy systems and their features

References:

1. Biogas Technology - A Practical Hand Book - Khandelwal, K. C. and Mahdi, S. S., Vol. I & II, Tata McGraw Hill Publishing Co. Ltd., 1983.
2. Biomass Conversion and Technology, C. Y. WereKo-Brobby and E. B. Hagan, John Wiley & Sons, 1996.
3. Food, Feed and Fuel from Biomass, Challal, D. S., IBH Publishing Co. Pvt. Ltd., 1991.
4. Non Conventional Energy, Desai, Ashok V., Wiley Eastern Ltd., 1990.

Course Articulation Matrix:

Course Outcomes	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	Identify various types of wastes from which energy can be generated	-	-	2	-	-	-
CO2	Describe biomass pyrolysis process and its applications	-	-	2	-	-	-
CO3	Appraise various types of biomass gasifiers and their operations	-	-	2	1	-	-
CO4	Evaluate biomass combustors and its applications on generating energy	2	-	2	2	-	-
CO5	Assess the principles of bio-energy systems and their features	-	-	2	-	-	-
Average CO		2	-	2	1.5	-	-

OBJECTIVES:

- To enable the students to learn the fundamentals of fluidization and its applications.
- To enable the students to understand the basic concept of hydrodynamics in fluidized bed.
- To impart knowledge on bubble dynamics in dense beds.
- To enable the students to encompass the new areas and introduce reactor models specifically for these Contacting regimes
- To enable the students to understand the fluidization behaviour, write model equations for fluidized beds and design gas-solid fluidized bed reactors

Introduction

Phenomenon of fluidization, behaviour of fluidized beds, Nature of hydrodynamic suspension, Characterization of particles, particle forces, Regimization of the fluidized state, operating models for fluidization systems, Industrial application of fluidized beds

Hydrodynamics of Fluidization Systems

General bed behaviour, pressure drop, pressure regimes, Incipient Fluidization, Pressure fluctuations, Phase Holdups, Measurements Techniques minimum fluidization velocity, pressure drop, Geldart classification of particles, Fluidization with carryover of particles, mapping of fluidization regimes

Dense Beds

Distributor types, gas entry region of a bed, gas jets in fluidized beds, pressure drop across distributors, design of a gas distributors, power consumption, Bubbles in dense beds: single rising bubbles, Davidson model for gas flow at bubbles, Evaluation of models for gas flow at bubbles, coalescence and splitting of bubbles, bubble formation. Slug flow

Bubbling Fluidized Beds, Entrainment and Elutriation

Effect of temperature and pressure on bed properties, Estimation of bed properties, bubble size and bubble growth, physical model and flow model- K-L Model with its Davidson bubbles and wakes, freeboard behaviour, entrainment from tall and short vessels, high velocity fluidization: turbulent fluidized beds and fast fluidization

Solid Movement, Mass and Heat Transfer

Solid movement, mixing, segregation and staging, gas dispersion and gas interchange in bubbling beds, Particle to gas mass and heat transfer: Experimental interpolation of mass transfer coefficients, experimental heat transfer from bubbling bed model, applications of two phase and three phase fluidized beds

Course Outcomes

- CO1: Recall the basics of fluidization and know the various industrial applications of fluidization
- CO2: Demonstrate the concepts of hydrodynamics in fluidized bed
- CO3: Describe the formation and growth of bubble dynamics in dense beds
- CO4: Analyze the bed behavior for various geometries of fluidized beds
- CO5: Evaluate the transport processes of fluidized beds

REFERENCES:

1. Kunii, D. and Levenspiel, O., "Fluidization Engineering", 2nd Edn., Butterworth Heinemann, London, 1990.
2. Fan, L. S., "Gas- liquid Solid Fluidization Engineering", Butterworths, 1989,
3. Kwauk, M., "Fluidization - Idealized and Bubbleless, with applications", Science Press, 2009

COURSE ARTICULATION MATRIX:

Course outcomes	Statements	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	Recall the basics of fluidization and know the various industrial applications of fluidization	-	-	3	-	-	-
CO2	Demonstrate the concepts of hydrodynamics in fluidized bed	-	-	2	1	1	-
CO3	Describe the formation and growth of bubble dynamics in dense beds	1	-	2	1	2	-
CO4	Analyze the bed behavior for various geometries of fluidized beds	1	-	2	2	1	-
CO5	Evaluate the transport processes of fluidized beds	1	-	1	1	2	-
Average CO		1	-	2	1.25	1.5	-

1, 2 and 3 are correlation levels with weightings as Slight (Low), Moderate (Medium) and Substantial (High) respectively

OBJECTIVES:

- To impart knowledge in nanocomposite materials in engineering applications
- To enable the students to learn and apply principles of various metal oxide nanocomposite preparation
- To enable the students to understand polymeric nanocomposite synthesis
- To enable the students to learn biological synthesis of nanocomposites
- To enable the students to understand preparation of natural nano composites

Introduction

Definition-importance of nanocomposites- nano composite materials-classification of composites- metal/ ceramics ,metal / polymer, Carbon – carbon composites, nanocomposites ,influence of size, shape and role of interface in composites applications.

Preparation and Properties

Hydroxyapatite composites with zirconia, alumina and titania – preparation and properties. SiC whisker reinforced hydroxyapatite and bioactive glass ceramics composites, zirconiatoughened and bioactive glass ceramics composites, bioglass-hydroxyapatite composites, carbon composites

Physical and Mechanical Properties

Elastic and strength properties – fracture behavior – fibre matrixload transfer–failure of a composite – criteria, damage of composites from physical and mechanisms to modeling, longterm behavior of composite materials, high temperature stability–wear and friction

Structures of Nanocomposites

Nanotubes, nanoparticles and inorganic-organic hybrid systems: Single walled carbonnanotubesin epoxy composites; Fullerene/carbon nano tube (CNT)composites; Filledpolymer nano composites containing functional nanoparticles; Polymer/calciumcarbonatenanocomposites;Magneticpolymer nanocomposites; Phenolic resin/SiO₂ organic-inorganic hybrid nanocomposites; Polymer/graphite nanocomposites; Wear resisting polymer nanocomposites: Preparation and properties

Natural Nanocomposites

Natural nanocomposites: Nanocomposites synthesized biologically; Nanocomposites synthesized by mimicking natural processes; Packaging proteins. Nanocomposite materials modeling: current issues. Multiscale modeling. Multi-physics modeling.

Course Outcomes:

- CO1: Demonstrate the various engineering application of nano composites.
 CO2: Explain various metal oxide nano composite preparation
 CO3: Determine the physical and chemical properties of nano composites
 CO4: Arrange biological synthesis of nano composites
 CO5: Design and develop natural nanocomposites and multiscale modeling.

References

1. Yiu-Wing Mai Zhong-Zhen Yu, Polymer Nanocomposites, 1st Edition, Wood head Publishing, 2006
2. Krishan Kumar Chawla, Composite Materials: Science and Engineering, Springer, 2012
3. Nanocomposite science and technology, Pulikel M. Ajayan, Wiley-VCH, 2005
4. Ajayan P.M. Nanocomposite Science and Technology, Wiley Verlag GmbH, Weinheim, 2003, ISBN 3-527-30359-6

Course Articulation Matrix:

Course Outcomes	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	Demonstrate the various engineering application of nano composites.	2	2	1	2	1	-
CO2	Explain various metal oxide nano composite preparation	2	1	1	2	1	-
CO3	Determine the physical and chemical properties of nano composites	2	2	-	2	1	-
CO4	Arrange biological synthesis of nano composites	-	3	1	-	-	2
CO5	Design and develop natural nanocomposites and multiscale modeling.	-	-	1	-	1	-
Average CO		2	2	1	2	1	2

1, 2 and 3 are correlation levels with weightings as Slight (Low), Moderate (Medium) and Substantial (High) respectively

Objectives:

- To enable the students, recall the fundamentals of Mass and Energy balance and to apply them in the design of various thermal processing methods
- To enable the students, understand the principle, equipment types of low temperature processing and preservation methods
- To impart knowledge of the drying techniques in food processing and preservation
- To enable the students comprehend the working principle and equipment types of different aseptic processing methods of food products
- To impart sound working knowledge of various emerging food processing and preservation technologies

Principles of Mass And Energy Balance

Material Balances-Basic Principles, Material Balance Problems Involved in Dilution, Concentration, and Dehydration, Blending of Food Ingredient, Multistage Processes; Energy Balances-General Principles, Enthalpy Changes in Foods During Freezing, Properties of Saturated and Superheated Steam. Heat balance.

Processing and Preservation By Low Temperature Methods

Use of low temperature – Principles, equipment and effect on quality: Chilling, cold storage. Principles of food freezing: freezing point of foods, Psychrometric chart, Freeze concentration, Freeze drying, IQF. New direction in freeze bed drying, cyclic pressure freeze drying. Freezing of foods, types of freezing equipment,. Methods of freeze concentration, design problems.

Drying

Principles of drying, drying rate, factors affecting heat and mass transfer during drying, properties of air-water mixtures; different drying methods: tray, drum, foam mat, spray, and other newer drying methods; construction and design of drying equipment; adiabatic driers. Dehydration of fruits, vegetables, milk, animal products and ready to eat food products. Design parameters of different types of dryers.

Aseptic Processing

Heat Sterilization. Canning and Retort treatment of foods; spoilage of canned foods, storage of canned foods; Influence of canning on the quality of food; improvement in canning technology. Pasteurization, TST and UHT treatment of milk, fruit juices and other liquid foods. In Package and In flow thermal processing equipment - plate, spiral and shell and tube heat exchangers.

Emerging Processing Technologies

High Pressure Processing – principles, mechanism of action, advantages and disadvantages over conventional processing; Equipment and applications in food industry, Pulsed electric field and Ultrasound processing - principles, mechanism of action, advantages and disadvantages over conventional processing; Equipment and applications in food industry. Dielectric and Ohmic heating of foods - principles, mechanism of action, advantages and disadvantages over conventional processing; equipment and applications in food industry. Infra – red heating – principles, mechanism of action food application. Principles of radiation processing, applications like disinfestation, pasteurization and sterilization, extending shelf life of plant products, advantages and limitations.

Course outcomes:

- CO1: Recognize and recall engineering principles to food processing
 CO2: Develop problem solving ability on types of loads and capability to design cold storage systems for food products
 CO3: Interpret the role of drying in the preservation of different foods
 CO4: Apply the principles of aseptic processing of foods
 CO5: Describe the recent developments in food processing and preservation techniques

References:

1. Toledo, R.M. "Fundamentals of Food Process Engineering", 3rd Edition, Springer, 2007
2. Fellows, P. J. "Food Processing Technology: Principles and Practices", Wood Head Publishing, 1997
3. Barbosa-Canovas, Gustavo et al., "Novel Food Processing Technologies", Marcel Dekker/CRC, 2005
4. Lopez, G.A. and Barbosa, C.G.V. "Food Plant Design", Taylor & Francis, 2005
5. S. Yanniotis, B. Sunden, Heat Transfer in Food Processing, Recent Developments and Applications, WIT Press, Southampton, 2007
6. Ranganna, S. "Handbook of Canning and Aseptic Packaging" Vol. I, II & III, Tata McGraw – Hill, 2000

Course Articulation Matrix:

Course Outcomes	Statement	Program Outcomes					
		PO1	PO2	PO3	PO4	PO5	PO6
CO1	Recognize and recall engineering principles to food processing	1	1	2	1	2	1
CO2	Develop problem solving ability on types of loads and capability to design cold storage systems for food products	1	1	3	1	1	-
CO3	Interpret the role of drying in the preservation of different foods	1	1	2	1	1	1
CO4	Apply the principles of aseptic processing of foods	1	1	2	1	1	-
CO5	Describe the recent developments in food processing and preservation techniques	1	1	2	1	1	1
Average CO		1	1	2.2	1	1.2	1

1, 2 and 3 are correlation levels with weightings as Slight (Low), Moderate (Medium) and Substantial (High) respectively

Objectives:

- To enable the students to learn the basics of bioprocessing
- To enable the students to understand the DNA structure
- To enable the students to calculate the mass and energy balances
- To enable the students to understand the upstream processes
- To enable the students to learn the downstream processes

Frontiers of Bioprocessing

Defining Bioprocessing, Current and Emerging Trends in Bioprocess Engineering, Materials Advances, Nanoscale advances, Bioprocessing for Chemical and Biologic Product Manufacturing, Bioprocessing Leaders Worldwide Economic Predictions and Careers in Bioprocess Engineering, Skills Needed for Future Bioprocess Engineers.

Introduction to Cellular Microbiology

DNA Structure, RNA Structure, Protein Structure and Function, Carbohydrates, Lipids, Fats, and Steroids, Basic Metabolic Pathways, General Cell Structure Eukaryotes, Prokaryotes, Archaea, and Viruses, Intracellular Organelles, Cellular Transport.

Reaction Stoichiometry, Thermodynamics, and Kinetics

Mass and Energy Balances, Fundamentals of Chemical Reactions, Basic Mass Transfer: Diffusion and Convection, Basic Fluid Dynamics, Basic Thermodynamics, Basic Reaction Kinetics.

Upstream Processing

Bioreactors, Batch Culture, Continuous Culture, Fed-Batch Culture, Perfusion Culture, Suspension Culture, Microcarrier Support ,Roller Bottle Culture System, Spinner Flask Culture, Other Scale up Options, Wave Bioreactor, Cell Cube Technology, Rotary Culture System ,Media

Down Stream Processing

Purification Processes - Centrifugation, adsorption, Electrophoresis, Crystallization Protein Properties, Chromatography, Scale-up and Optimization,

Course Outcomes:

- CO1: Recognize all Bioprocesses and need of chemical basics in bioprocesses.
CO2: Describe the basic of cell and its internal constituents
CO3: Apply reaction mechanisms in terms of chemical kinetics.
CO4: Analyze all unit operations in upstream process in manufacturing Industries.
CO5: Evaluate the downstream processing and industrial bioreactors

References:

1. Bioprocess engineering principles, Pauline M. Doran, 2nd ed, Academic Press, 2012.
2. Biochemical engineering fundamentals by J.E.Bailey and D.F.Ollis, 2nd ed, 1986, McGraw Hill.
3. Bioprocess Engineering by Michael L. Shuler and Fikret Kargi, 2nd edition, Pearson education.
4. Biochemical engineering by James M.Lee – Prentice-Hall-1992
5. Fundamentals of Modern Bioprocessing by Sarfaraz K. Niazi, Justin L. Brown, CRC Press, 2017.
6. Biochemical Engineering, H.W. Blanch and D.S. Clark, Marcel Dekker, 1997

Course Articulation Matrix:

Course Outcomes	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	Recognize all Bioprocesses and need of chemical basics in bioprocesses.	-	3	1	2	-	-
CO2	Describe the basic of cell and its internal constituents	1	1	1	2	-	-
CO3	Apply reaction mechanisms in terms of chemical kinetics.	-	3	1	2	3	-
CO4	Analyze all unit operations in upstream process in manufacturing Industries.	3	1	1	3	2	-
CO5	Evaluate the downstream processing and industrial bioreactors	1	2	1	-	-	-
Average CO		3	1	2	1	2	1

1, 2 and 3 are correlation levels with weightings as Slight (Low), Moderate (Medium) and Substantial (High) respectively

Objectives:

- To impart knowledge on basics of CFD and reminisce conservation principle
- To enable the students to understand discretization techniques
- To explain the numerical analysis of solving diffusion in 1D, 2D and 3D
- To explain the numerical analysis of solving of convection-diffusion problems
- To impart the knowledge of turbulence modelling and grid generation

Introduction and Principles of Conservation

Basics of Computational Fluid Dynamics, Illustration of the CFD approach, CFD as an engineering analysis tool, CFD application in Chemical Engineering, Fundamental principles of conservation, governing equations of fluid flow, heat and mass transfer. Equations of continuity, motion and energy in differential and integral forms, conservation and non-conservation form.

Discretisation Techniques : Finite Difference Approximation

Classification of Partial Differential Equations, Mathematical behaviour of PDE, Basic aspects of discretization, Discretization techniques using finite difference methods – Taylor's Series, explicit and implicit methods. Error and stability analysis

Diffusion Processes: Finite Volume Method

Steady one-dimensional diffusion, two and three dimensional steady state diffusion problems, Solution of discretised equations.

Convection - Diffusion Processes: Finite Volume Method

One dimensional convection – diffusion problem, Central difference scheme, upwind scheme, Hybrid and power law discretization techniques, QUICK scheme, Assessment of discretization scheme properties, Solution of discretised equations.

Turbulence Modeling And Grid Generation

Characteristics of turbulent flows, time averaged Navier Stokes equations, turbulence Models – one and two equation, Reynolds stress, LES and DNS. Physical aspects of Grid generation, staggered grid, SIMPLE algorithm, PISO algorithm

Course Outcomes:

- CO1: Describe the basics of CFD and governing equations for conservation of mass momentum and energy
- CO2: Analyze the mathematical characteristics of partial differential equations.
- CO3: Solve computational solution techniques for time integration of ordinary differential equations
- CO4: Formulate various discretization techniques used in CFD
- CO5: Assess various turbulence models and grid generation techniques

References:

1. Anderson, J. D., "Computational Fluid Dynamics: The Basics with Applications", McGraw Hill, 1995.
2. Versteeg, H.K. and Malalasekera, W., "An Introduction to Computational Fluid Dynamics: The Finite Volume Method", Pearson Education Ltd., 2007.
3. Chung T.J Computational Fluid Dynamics Cambridge University Press 2003.
4. Fletcher, C. A. J., "Computational Techniques for Fluid Dynamics", Springer Verlag, 1997.

5. Muralidhar, K., and Sundararajan, T., "Computational Fluid Flow and Heat Transfer", Narosa Publishing House, New Delhi, 2001.
6. Ghoshdastidar, P.S., "Computer Simulation of flow and heat transfer" Tata McGraw – Hill Publishing Company Ltd. 1998.
7. Subas, V. Patankar "Numerical heat transfer fluid flow", Hemisphere Publishing Corporation, 1980.
8. Taylor, C and Hughes, J.B. "Finite Element Programming of the Navier Stoke Equation", Pineridge Press Limited, U.K., 1981.

Course Articulation Matrix:

Course Outcomes	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	Describe the basics of CFD and governing equations for conservation of mass momentum and energy	-	-	-	2	-	-
CO2	Analyze mathematical characteristics of partial differential equations.	1	-	2	1	2	2
CO3	Solve computational solution techniques for time integration of ordinary differential equations	1	-	2	3	3	2
CO4	Formulate various discretization techniques used in CFD	1	-	2	3	2	2
CO5	Assess various turbulence models and grid generation techniques	-	-	2	1	1	1
Average CO		1	-	2	2	2	1.75

1, 2 and 3 are correlation levels with weightings as Slight (Low), Moderate (Medium) and Substantial (High) respective

OBJECTIVE:

To focus on the wastewater transport system and the theory and design technique for the wastewater treatment process

Internal Treatment Process

Character and properties – Water problem and solution – Water Sedimentation - Coagulation – Filtration – Disinfection – Theory, necessity, process, equipment, application, location, limitation.

External Treatment Process

Softening by Ion – exchange process, Demineralization – Cation exchange materials – Removal of ion, Manganese, odour, colour taste – Deaeration – Oxidation – Fluoridation– Dealkalisation – Desalination by Reverse osmosis.

Boiler Water and Cooling Water

Concept – Importance – Location – Commonly used desalination process – Distillation – Electro dialysis – Reverse osmosis – Freezing – Solar distillation- Purpose – Problem associated with water quality and equipment – Steam system fundamentals – Hot water closed system – Measurement and control of pH, corrosion, fouling – Microbial analysis – Ozone control – Study of microorganism – Energy efficient operations and maintenance.

Waste Water Treatment

Waste water in Industry- Home and Agriculture – Various waste water treatment processes – Optimization – Benefits and costs – Microbial and sanitation water treatment – Biofilm formation and removal – Microbial trend analysis – Pretreatment system and equipment.

Water Management in India

Water resources and planning – Water policy – Indian scene – Main aspects of water management – Hydrological cycle – Hydrosphere – Water transport – Water exchange – Causes and problems in irrigation, rural water, urban water – Water conservation resource management - Rain Harvesting.

References:

1. P.C.Bansil "Water Management in India", Concept Publishing company, New Delhi, First Edition, 2004.
2. G.S.Bridie and J.S.Bridie "Water Supply and Sanitary Engineering", Dhanpat Raj Publishing company (P) Ltd., New Delhi, 7th Edition, 2003.
3. Austin G.T., "Shreve's Chemical Process Industries", Fifth Edition, McGraw Hill, 1998.

4. S.C. Rangwala, "Water supply and Sanitary engineering", Eighteenth Edition, Charotar Publishing House, 2003.
5. Pandey G.N., "Text Book of Chemical Technology", Vikas Publishing House Pvt. Ltd., New Delhi, 1992

Course Outcomes	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	Explain water characteristics and internal treatment processes.	-	-	-	1	-	-
CO2	Apply external water treatment methods for impurity removal.	2	3	1	1	2	2
CO3	Analyze boiler and cooling water systems and their quality control.	1	-	2	3	2	2
CO4	Evaluate wastewater treatment processes and optimization methods.	2	3	1	1	2	2
CO5	Assess water resource management and conservation practices in India.	-	-	1	1	1	1
Average CO		2	3	1	1	2	2

Objectives:

- To enable the students to understand the classification of biomass and composition of biomass.
- To enable the students to understand different type of pre-treatment techniques.
- To impart knowledge on various methods of bio energy generations.
- To impart knowledge on the various biomass conversion techniques.
- To enable the students to understand the concept of bio refinery process.

Introduction

World energy scenario, consumption pattern, fossil fuel depletion and environmental issues, Biomass availability and abundance, Biomass conversion processes – Biological – Thermal – Chemical – Hybrid conversions – Application of biomass conversion products – Biomass properties for conversion process – Physical properties, Proximate, Ultimate and heating value analysis.

Biomass Pretreatment

Barriers in lignocellulosic biomass conversion, role of pretreatment in bioenergy conversion, pretreatment technologies such as chemical, physical and physic chemical methods, hybrid methods, Torrefaction – products obtained – properties of torrefied biomass – Physical and chemical – composition changes – torrefaction as pretreatment process, Briquetting: types of Briquetting – merits and demerits.

Bio Fuel Generation

Bioethanol and Biobutanol generation from lignocellulosic biomass, microorganisms for fermentation, current industrial ethanol production technology, cellulases and their role in hydrolysis, advanced fermentation technologies, ABE fermentation pathway and kinetics, product recovery technologies. Biohydrogen generation, metabolic basics, feed stocks, dark fermentation by strict anaerobes, facultative anaerobes, thermophilic microorganisms, integration of biohydrogen with fuel cell; fundamentals of biogas technology, fermenter designs, biogas purification, methanol production and utilization.

Biomass Conversion Techniques

Biomass combustion Process, Biomass gasification – chemistry – types of gasifiers – gasifier design, Biomass Pyrolysis process, various reactor used for biomass combustion, Gasification and Pyrolysis process. Factors affecting biooil, biochar production, fuel properties, bio-oil upgradation. Biodiesel: Diesel from vegetable oils, microalgae and syngas; transesterification; FT process, catalysts; biodiesel purification, fuel properties

Biorefinery

Basic concept, types of biorefineries, biorefinery feed stocks and properties, economics, Concept, corn/soybean/sugarcane biorefinery, lignocellulosic biorefinery, aquaculture and algal biorefinery, waste biorefinery, hybrid chemical and biological conversion processes, techno- economic evaluation, life-cycle assessment.

Course Outcomes:

- CO1: Classify types of biomasses and estimate the composition of biomass.
 CO2: Explain different type of pre-treatment techniques.
 CO3: Analyze the various methods of bio energy generations.
 CO4: Describe the various biomass conversion techniques.
 CO5: Assess the concept of bio refinery process.

References:

1. Sergio C. C. Introduction to Biomass Energy Conversions, First Edition, CRC Press, 2019.
2. David .B, Bio Energy Technology Thermodynamics and costs, Prentice Hall Europe, 1984
3. Sergio C. C., Introduction to Renewable Energy Conversions, CRC Press,2019.
4. Were Ko-Brobby C. Y., Hagan. E. B., Biomass Conversion and Technology, John Wiley & Sons, 1996
5. Mahaeswari, R.C. Bio Energy for Rural Energisation, Concepts Publication,1997

Course Articulation Matrix:

Course Outcomes	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	Classify types of biomasses and estimate the composition of biomass.	3	2	2	1	1	1
CO2	Explain different type of pre-treatment techniques.	3	2	2	1	1	-
CO3	Analyze the various methods of bio energy generations.	3	2	-	1	-	1
CO4	Describe the various biomass conversion techniques.	3	2	2	1	1	1
CO5	Assess the concept of bio refinery process.	-	2	2	1	1	-
Average CO		3	2	2	1	1	1

1, 2 and 3 are correlation levels with weightings as Slight (Low), Moderate (Medium) and Substantial (High) respectively.

Objectives:

- To impart knowledge on the types of polymers, polymerization reactions, polymerization techniques.
- To impart knowledge on processing of elastomers and application-oriented polymers.
- To enable the students to learn the analytical characteristics of polymers
- To enable the students to learn the testing procedures of polymer composites
- To impart knowledge on polymer composites

General Aspects of Polymers

Classification of polymers - natural and synthetic, thermoplastic and thermosetting; types and mechanism of polymerization reactions; polymerization techniques; Polymer properties - degree of polymerization, molecular weight determination, glass transition temperature, crystallinity, thermal, electrical and mechanical properties.

Polymer Processing

Process additives and significance; types of additives; mixing processes; Types of moulds; mould cooling and ejection techniques; moulding - extrusion moulding, injection moulding, blow moulding and other moulding techniques.

Elastomers and Application Oriented Polymers

Natural Rubber and synthetic rubber; unit operations; styrene – butadiene, polyisoprene – neoprene, silicone rubber, thermoplastic elastomers; Resins – epoxy, phenol formaldehyde, urea formaldehyde; fibrous Polymers - Nylon 66, PAN; PVC, Silicon Oil.

Polymer Testing and Characterization

Analytical tests - determination of specific gravity, water absorption; Non-destructive testing - ultrasonic testing, Acoustic emission (AE) testing, thermal stability, X-ray fluorescence, FT-IR, XRD, SEM, AFM, etc.

Polymer Composites

Polymer composites and general concepts; structure and components of polymer composites; classification of polymer composites; hybrid composites; usage areas of composites in daily life.

Course Outcomes:

- CO1: Recall the fundamentals of polymers and mechanism of polymerization techniques and polymer properties.
- CO2: Apply the mechanism and effectiveness of polymerization in making finished materials.
- CO3: Demonstrate the knowledge of elastomers and its processing.
- CO4: Construct the knowledge of analytical characteristics of polymer.
- CO5: Assess the general aspects of polymer composite materials.

References:

1. Birley, Haworth, Batchelor, "Physics of Plastics – Processing Properties and Materials Engineering", Hamer Publication, 1992.
2. Billmeyer F.W., "Text Book of Polymer Science" 3rd Ed., John Wiley and sons, New York, 2002.
3. Richard G. Griskey, "Polymer Process Engineering", Chapman and Hall, 1995.
4. Vishu Shah, "Hand book of Plastics Testing and Failure Analysis", 3rd Ed., John-Willey & Sons, New York, 2007.
5. Sabu Thomas, Kuruvilla Josep, "Polymer Composites: Volume 1" 1st Ed., Wiley, 2012.

Course Articulation Matrix:

Course Outcomes	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	Recall the fundamentals of polymers and mechanism of polymerization techniques and polymer properties.	-	1	-	2	3	3
CO2	Apply the mechanism and effectiveness of polymerization in making finished materials.	3	3	1	3	3	3
CO3	Demonstrate the knowledge of elastomers and its processing.	3	3	1	3	3	3
CO4	Construct the knowledge of analytical characteristics of polymer.	-	3	1	-	3	3
CO5	Assess the general aspects of polymer composite materials.	3	3	1	3	3	3
Average CO		2	2.6	1	2.75	3	3

1, 2 and 3 are correlation levels with weightings as Slight (Low), Moderate (Medium) and Substantial (High) respectively

Objectives:

- To enable the students to learn the basics of Business Analytics
- To enable the students understand and analyze descriptive analytics and Hypothesis testing
- To impart knowledge on Data Analytics and Data Visualization
- To enable the students understand and analyze Predictive Analytics
- To enable the students understand and analyze Prescriptive Analytics

Introduction to Business Analytics (BA)

Business Analytics - Terminologies, Process, Importance, Relationship with Organisational Decision Making, Analytics in Decision Making, BA for Competitive Advantage- Organisational Structures aligning BA. Managing Information policy

Descriptive Analytics and Hypothesis Testing

Data and Technology- data quality and change in BA- Descriptive and Inferential Statistics- Mean/Median/Mode-Standard Deviation/Covariance/Correlation - Sampling And Estimation - Probability Distribution For Descriptive Analytics - Analysis Of Descriptive Analytics- Hypotheses testing

Data Analytics and Data Visualization

An introduction to Data Analytics- Role of Analytics in the Modern World-Types of Analytics: Descriptive, Diagnostic, Predictive, Prescriptive-Data Analytics and Ethical Issues, Data visualizations : Create Visual Representations Of Data In Excel - Create Scatter Plots And Calculate The Correlation Coefficient, Create Boxplot, Create, Histogram and line chart

Predictive Analytics

Introduction to Predictive analytics - Logic and Data Driven Models - Predictive Analysis Modeling and procedure - Data Mining for Predictive analytics. Analysis of Predictive analytics.

Prescriptive Analytics

Introduction to Prescriptive analytics - Prescriptive Modeling - Non Linear Optimisation - Demonstrating Business Performance Improvement.

Course outcomes:

- CO1: Recall the basics of Business Analytics
 CO2: Analyze and apply descriptive analytics and Hypothesis testing
 CO3: Illustrate Data Analytics and Data Visualization
 CO4: Formulate Predictive Analytics
 CO5: Evaluate Prescriptive Analytics

References:

1. Fundamentals of Business analytics, 2nd Edition, R.N. Prasad and Seema Acharya, Wiley India Pvt Ltd, 2016.
2. Business analytics, U. Dinesh Kumar, Wiley Publisher, 2017.
3. Business analytics-data analysis and decision making with mind map, 7th edition, S. Christian Albright and Wayne L. Winston, 2022.

4. Business analytics methods, models and decisions, 3rd edition, James R Evans, 2017.
5. Business analytics for decision making, 1st edition, Regi Mathew, 2020.

Course Articulation Matrix:

Course Outcomes	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	Recall the basics of Business Analytics	3	1	2	3	3	1
CO2	Analyze and apply descriptive analytics and Hypothesis testing	3	1	2	3	3	1
CO3	Illustrate Data Analytics and Data Visualization	3	1	2	3	3	1
CO4	Formulate Predictive Analytics	3	1	2	3	3	1
CO5	Evaluate Prescriptive Analytics	3	1	2	3	3	1
Average CO		3	1	2	3	3	1

1, 2 and 3 are correlation levels with weightings as Slight (Low), Moderate (Medium) and Substantial (High) respectively

Objectives:

- To enable the students to understand the pollutants released from various chemical industries.
- To familiarize the students on options for pollution prevent in chemical processes.
- To impart knowledge on pollutant measurement techniques.
- To develop student's ability to frame management strategies for the control of pollution.
- To make the students understand the regulation pertaining to pollutant discharge.

Industrial Pollutants Its Measurement

Introduction- pollution from chemical process industries, characterization of emission and effluents, standards for ambient air, noise emission and effluents; Analysis of pollutant; Pollutant measurement- Fundamental Units of Measurement – Mass Concentration Parts Per Million and mg/l, Mass Percentage and Mass Fraction, Mass Flow Rates, volume Fraction and Volume Concentration; Converting Volume and Mass Concentration in Gases – Molar Mass and Molar Concentration – Equivalent Weights

Pollution Prevention For Chemical Processes

Pollution Prevention for Unit Operations; Preventing Fugitive and Secondary Emissions; Flowsheet Analysis for Pollution Prevention; Management of Pollution Prevention Activities at Industrial Facilities - 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.

Elements of Pollution Prevention Programs

The Waste Management Hierarchy and the Definition of Pollution Prevention; An Industrial Perspective of Pollution Prevention-The Benefits of Pollution Prevention, Barriers to Pollution Prevention (Industrial Barriers – Regulatory Barriers); The Basic Structure of a Pollution Prevention Program - Identifying Critical Waste Streams; Waste Audits – Emission Inventories (Fugitive Emissions – Secondary Emissions) – Prioritizing Waste Streams.

Pollution Control

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

Regulations Governing Pollutant Emissions

Regulations concerning water pollution-WATER (P&CP) ACT, 1974; air pollution- AIR (P&CP) ACT, 1981; solid waste -hazardous Wastes-Hazardous and other Wastes (Management & Transboundary Movement) Rules, 2016; Pollution Prevention Case Study.

Course Outcomes:

- CO1: Identify importance of pollutant measurement and different types of pollution
 CO2: Classify pollution control options for different chemical processes.
 CO3: Design Hierarchy of Pollution Prevention strategy.
 CO4: Choose equipment for pollution control.
 CO5: Illustrate regulations governing pollution prevention preventive

References:

1. Nancy J. Sell, Industrial pollution control: Issues and techniques.
2. Berthouex, P. M., Brown, L. C. (2017). Chemical Processes for Pollution Prevention and Control. United Kingdom: CRC Press
3. "Pollution Control Acts, Rules, Notifications issued there under" CPCB, Ministry of Env. and Forest, G.O.I., 3rd Ed. 2006.
4. Allen, D. T., Rosselot, K. S. Pollution Prevention for Chemical Processes: A Handbook with Solved Problems from Refining and Chemical Processing Industries (1994).
5. Bishop P.E. Pollution Prevention: Fundamentals and Practice, McGraw Hill

Course Articulation Matrix:

Course Outcomes	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	Identify importance of pollutant measurement and different types of pollution	-	3	1	2	-	-
CO2	Classify pollution control options for different chemical processes.	1	1	1	2	-	-
CO3	Design Hierarchy of Pollution Prevention strategy.	-	3	1	2	3	-
CO4	Choose equipment for pollution control.	3	1	1	3	2	-
CO5	Illustrate regulations governing pollution prevention preventive	1	2	1	-	-	-
Average CO		1	2	1	2	1	-

1, 2 and 3 are correlation levels with weightings as Slight (Low), Moderate (Medium) and Substantial (High) respectively

Objectives:

- To enable the students to learn the principles and terminology related to risk management
- To enable the students to understand the basic quantitative methods on risk identification and risk management
- To impart knowledge on the concepts of risk analysis and management in chemical industries
- To impart knowledge on emergency planning and insurance
- To impart knowledge on handling risk analysis in chemical industries

Introduction

Identify key risks; measure probability and impact; risk types; root cause analysis and decision making.

Risk Assessment and Hazard Identification

introduction and available methodologies - quantitative risk assessment, rapid risk analysis, comprehensive risk analysis; risk identification; evaluation and control of risk; uncertainty in risk assessment; hazard identification - hazard assessment, probabilistic hazard assessment, fault tree analysis, event tree analysis, zero infinity dilemma.

Risk Management

Risk management plan; mandatory technology option analysis; risk management alternatives; risk management tools; risk management plans; risk index methods; precautionary principles; risk perceptions and communication; behavioral decision making.

Emergency Planning and Insurance

Overall risk contours for different failure scenarios; disaster management plan; emergency planning; onsite and offsite emergency planning; overview of insurance and risk transfer- property insurance, transport insurance, liability insurance, pecunious insurance.

Risk Analysis in Chemical Industries

Handling and storage of chemicals; process plants; personnel protection equipments; environmental risk analysis; international environmental management system; corporate management system; environmental risk assessment; total quality management; paradigms and its convergence.

TOTAL: 45 PERIODS**COURSE OUTCOMES:**

- CO1: Recall the general aspects of risk analysis and management.
CO2: Apply different tools to aid the risk assessment analysis
CO3: Identify characteristics of risk management system
CO4: Assess onsite and offsite emergency planning.
CO5: Analyze risk in Process industries and manage the risks.

References:

1. Srivastav, S., "Industrial Maintenance Management", Sultan Chand & Co., 1998.
2. Crowl, D. A. and Louvar, J. F., "Chemical process safety; Fundamentals with applications", Prentice Hall Publication Inc., 2002.
3. Fawcett, H. H., "Safety and Accident Prevention in Chemical Operations" John Wiley & Sons, 1982.
4. Kind, R. W., "Industrial Hazard and Safety Handbook" Butterworth, 1982.
5. Steiner, H. M., "Engineering Economic Principles", McGraw Hill Book Co., New York, 1996.

Course Articulation Matrix:

Course Outcomes	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	Recall the general aspects of risk analysis and management.	2	3	2	-	-	1
CO2	Apply different tools to aid the risk assessment analysis	2	3	2	3	2	3
CO3	Identify characteristics of risk management system	2	3	2	3	2	3
CO4	Assess onsite and offsite emergency planning.	3	3	2	1	2	3
CO5	Analyze risk in Process industries and manage the risks.	3	3	2	3	2	3
Average CO		2.4	3	2	2.5	2	2.6

1, 2 and 3 are correlation levels with weightings as Slight (Low), Moderate (Medium) and Substantial (High) respectively

Objectives:

- To enable the students to understand the scope of project engineering
- To enable the students to learn the procedures for procurement and operations
- To enable the students to learn design and selection of pumps, compressors and their accessories
- To impart knowledge on design and selection of piping and building constructions
- To enable the students to learn the evaluation techniques in project engineering

Scope

Scope of project engineering – the role of project engineer – R & D – TEF – plant location and site selection – preliminary data for construction projects – process engineering – flow diagrams – plot plans – engineering design and drafting. Planning and scheduling of projects – bar chart and network techniques.

Procedures

Business and legal procedures: Procurement operations, Organization and operation of procurement department, Procurement procedure, General purchaser-vendor practices, contracts and contractors, project financing, statutory sanctions.

Design and Selection – I

Details of engineering design and equipment selection – design calculations excluded - Vessels, heat exchangers, process pumps, compressors and vacuum pumps, motors and Turbines, other process equipment.

Design and Selection - II

Details of engineering design and equipment selection II – design calculations excluded – piping design, thermal insulation and buildings, safety in plant design, plant constructions, start up and commissioning.

Evaluation

Critical path method (CPM) and Programme evaluation and review technique (PERT) in project engineering.

Course Outcomes:

- CO1: Recognize the scope of project engineering.
CO2: Analyze and apply the procedures for procurement and operations.
CO3: Choose pumps, compressors and their accessories.
CO4: Design and selection of piping and building constructions.
CO5: Evaluate the reviewing techniques in project engineering.

References:

1. Peter Watermeyer , Handbook for Process Plant Project Engineers, Wiley, 2002
2. Howard F. Rase, M. H. Barrow, Project engineering of process plants, Wiley, 1957
3. Peter S. Max & Timmerhaus, Plant design and economics for chemical engineers, Mc Graw Hill, 2002.
4. B. C. Punmia & K. K. Khandelwal, Project Planning and Control with PERT & CPM, Firewall Media, 2002
5. Srinath L. S., PERT AND CPM, 3rd Edn Affiliated East Press Pvt. Ltd., New York, 2001.
6. Perry J. H, "Chemical engineering handbook" 7th ed. McGraw Hill, 1997.

7. Ernest E. Ludwig, Applied project engineering and management, Gulf Pub. Co, 1988.
8. R K Sinnott, Chemical Engineering Design: Chemical Engineering Design, Chemical Engineering Technical Series, Elsevier, 2014.

Course Articulation Matrix:

Course Outcomes	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	Recognize the scope of project engineering.	1	3	3	3	3	3
CO2	Analyze and apply the procedures for procurement and operations.	3	2	3	3	3	3
CO3	Choose pumps, compressors and their accessories.	3	1	3	3	3	3
CO4	Design and selection of piping and building constructions.	3	1	3	3	3	3
CO5	Evaluate the reviewing techniques in project engineering.	3	3	3	3	3	3
Average CO		3	2	3	3	3	3

1, 2 and 3 are correlation levels with weightings as Slight (Low), Moderate (Medium) and Substantial (High) respectively.

OBJECTIVES:

- To enable the students to solve linear programming problem and solve using graphical method.
- To enable the students to solve LPP using simplex method
- To enable the students to solve transportation, assignment problems
- To enable the students to solve project management problems
- To enable the students to solve scheduling problems

Linear Programming

Introduction to Operations Research – assumptions of linear programming problems - Formulations of linear programming problem – Graphical method

Advances in Linear Programming

Solutions to LPP using simplex algorithm- Revised simplex method - primal dual relationships – Dual simplex algorithm - Sensitivity analysis

Network Analysis – I

Transportation problems -Northwest corner rule, least cost method, Voges's approximation method - Assignment problem -Hungarian algorithm

Network Analysis – II

Shortest path problem: Dijkstra's algorithms, Floyds algorithm, systematic method - CPM/PERT

Network Analysis – III

Scheduling and sequencing - single server and multiple server models - deterministic inventory models - Probabilistic inventory control models

Course Outcomes:

CO1: Formulate linear programming problem and solve using graphical method.

CO2: Practice LPP using simplex method

CO3: Solve transportation, assignment problems

CO4: Analyze project management problems

CO5: Evaluate scheduling problems

References:

1. Harvey M Wagner, Principles of Operations Research: Prentice Hall of India 2010.
2. Hitler Libermann, Operations Research: McGraw Hill Pub. 2009.
3. Pant J C, Introduction to Optimisation: Operations Research, Jain Brothers, Delhi, 2008.
4. Pannerselvam, Operations Research: Prentice Hall of India 2010.
5. Taha H A, Operations Research, An Introduction, PHI, 2008

Course Articulation Matrix:

Course Outcomes	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	Formulate linear programming problem and solve using graphical method.	1	2	2	2	3	3
CO2	Practice LPP using simplex method	1	1	3	1	3	3
CO3	Solve transportation, assignment problems	1	1	3	2	3	3
CO4	Analyze project management problems	1	2	3	2	3	3
CO5	Evaluate scheduling problems	1	2	3	2	2	3
Average CO		1	2	3	3	2	3

1, 2 and 3 are correlation levels with weightings as Slight (Low), Moderate (Medium) and Substantial (High) respectively.

Objectives:

- To make the students analyze the Root causes of accidents and effects on human beings and materials
- To enable the students to understand the theories, structures and prevention of accidents
- To impart knowledge on industrial safety of a chemical process plant.
- To enable the students to understand the applications and advantages of good house keeping
- To enable the students to learn the Disaster managements and various issues

Legislation and Policy

Safety, safety responsibility and organization, OHS, safety policy, safety inspection, employees participation in safety, safety legislation, plant siting and layout, utilities and safety, regulatory agencies with safety in India and Abroad, types of accidents in industry, case study.

Industrial Hazard and Assessment

Industrial hazard, hazard management program, hazard identification and assessment, Material hazard: Toxicity, Radiation, Flammability, fires, explosion, runaway chemical reaction, MSDS sheet, list of industries involving hazardous process, Factory Act, 1948

Hazard Control

Environment, Need for environment control, lighting, importance of adequate lighting, lighting design, colour codes used in industry, heat control, ventilation and air conditioning, legal requirements, noise, noise measurement and control, vibration, industrial fatigue, EIA

Waste Classifications and PPE

Industrial waste, waste classification, waste water treatment, waste disposal, storage, transportation of hazardous materials occupational health problems, Fire management, medical examination in industry, PPE, Training & Maintenance of PPE.

Safety Standards and Audit

Quality standards, ISO 9000, ISO9000 : 2000 Quality Management principles, Benefits, workplace emergency, emergency planning, on-site and offsite planning, fire emergency procedure, safety symbols, safety signs and colour at work, training, safety audit.

Course Outcomes

- CO1: List the importance of industrial safety and safety regulations all over the world.
- CO2: Discuss the effect of material hazard Evaluate the importance of EIA in chemical industries
- CO3: Classify the industrial waste and recommend the relevant PPE
- CO4: Describe quality management principles and the importance of emergency planning.
- CO5: Practice industrial safety, environmental impact, rules and regulations

References:

1. Industrial Safety and Environment, Amit Kumar Gupta, Laxmi Publications Ltd., 2006
2. Chemical process industrial safety, KSN Raju, McGraw Hill, 2014
3. M.N.Vyas, Safety and hazards management in chemical industries, Atlantic publishers, 2020
4. Lees' Loss Prevention in the Process Industries: Hazard Identification, Assessment and Control, Volume 1, edited by Sam Mannan, third edition, 2005
5. Pravin M. Pathak, Jayant P. Khairnar Industrial Safety Management : Safety Health And Environment Management, 2022

Course Articulation Matrix:

Course Outcomes	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	List the importance of industrial safety and safety regulations all over the world.	1	3	1	2	1	1
CO2	Discuss the effect of material hazard Evaluate the importance of EIA in chemical industries	1	1	1	2	1	1
CO3	Classify the industrial waste and recommend the relevant PPE	2	3	1	2	3	1
CO4	Describe quality management principles and the importance of emergency planning.	3	1	1	3	2	1
CO5	Practice industrial safety, environmental impact, rules and regulations	1	2	1	1	2	1
Average CO		1.6	2	1	1.8	1.8	1

1, 2 and 3 are correlation levels with weightings as Slight (Low), Moderate (Medium) and Substantial (High) respectively.

Course Objectives:

- I. Visualize data to understand relationships and assess data quality
- II. Understand the differences between classification, regression, and clustering and when each can be applied Review theory and applications of machine learning to engineering applications utilizing unsupervised and supervised learning methods
- III. Master the use of machine learning packages with
- IV. understanding of how hyper parameters can be adjusted to improve performance
- V. Implement machine learning techniques successfully to complete a group project

Fundamentals of AI and Applications

Definition, historical overview, applications, AI, ML, deep learning: differences and overlap, Ethical considerations (bias, transparency, interpretability), Applications in chemical engineering. **Python Basics and Data Handling:** Intro to python and Jupyter notebooks, Data handling with python, Data manipulation with Pandas, Python for basic statistics.

Data Visualization and Scientific Computing

Basic libraries: Numpy, Scipy, Matplotlib, Seaborn, Solving linear, nonlinear, interpolation, curve-fitting and ordinary differential equation problems Data visualization with Matplotlib, Solving chemical engineering problems

Data Engineering

Data gathering, types of data, data quality ,Data cleaning, handling missing values, outlier ,detection, Feature engineering (Selecting and transforming features) Data scaling and normalization, dealing with imbalanced data.

Introduction to Machine Learning

Overview of supervised learning and applications, Regression models: Linear regression, K-nearest neighbors (KNN), simple neural network regressor. Classification Models: Decision trees, random forests, KNN classifier, Evaluation metrics for regression and classification (e.g., MAE, MSE, accuracy, confusion matrix).

Introduction to Neural Networks

Fundamentals: neurons, layers activation Functions, Introduction to neural network architectures, Simple neural network example using Keras, Applications in chemical engineering: process optimization, predictive maintenance (time-series data), Clustering techniques (K-means) for anomaly detection in chemical processes.

References:

1. Müller, A. C., & Guido, S. (2016). Introduction to Machine Learning with Python: A Guide for Data Scientists. O'Reilly Media.
2. Gopal, M. (2019). Applied Machine Learning. McGraw Hill.
3. Quantrille, T. E., & Liu, Y. A. (2012). Artificial Intelligence in Chemical Engineering. Elsevier.
4. McCarran, R. G. (2021). Machine Learning for Engineers. Springer.

Course Outcomes	Statement	Program Outcomes					
		PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO1	Explain fundamentals of AI, ML, DL, and their applications in chemical engineering.	-	-	1	2	1	1
CO2	Apply Python and data analysis tools for scientific computing and statistics.	2	3	1	2	2	1
CO3	Solve engineering problems using numerical methods and data visualization techniques.	2	3	1	2	2	1
CO4	Perform data preprocessing and feature engineering for machine learning tasks.	2	3	1	3	2	1
CO5	Develop and evaluate machine learning and neural network models for engineering applications.	2	2	1	1	2	1
Average CO		2	3	1	2	2	1

Course Objectives

This course introduces the basics of data analytics, data sources in process industries, data-driven prediction and control, and process optimization using available data.

Process Data Analytics for Process Industries

Fundamentals of Process Data Analytics -Scope and challenges of process data analytics in chemical and allied industries; Statistical thinking for process systems; Data analytics vs machine learning vs AI; Types of industrial data (steady-state, dynamic, batch); Exploratory data analysis for process data; Multivariate statistics and visualization; Outlier detection and missing data treatment; Correlation and cross-correlation analysis.

Process Data Sources and Data Management -Plant data and historian systems; Sensor characteristics and data quality issues; Data acquisition from laboratory, pilot plant, and simulation studies; Synthetic and digital twin-generated data; Data cleaning and pre-processing; Data reconciliation and gross error detection; Time-series alignment; Data storage and management practices.

Data-Driven Modelling for Prediction- Framework for data-driven modelling of process systems; Linear and nonlinear regression with regularization; Kernel-based and tree-based models; Neural networks for process prediction; Time-series modelling for dynamic processes; Model validation, performance metrics, and uncertainty; Correlation versus causality in process data.

Data-Driven Process Monitoring, Control, and Optimization -Multivariate process monitoring using PCA and PLS; Fault detection and diagnosis; Data-driven PID tuning and adaptive control; Model predictive control using data-driven and hybrid models; Introduction to reinforcement learning for process control; Optimization of process performance using gradient-based and evolutionary methods; Multi-objective optimization and Pareto analysis.

Case Studies and Software Implementation-Industrial case studies in chemical, energy, and pharmaceutical processes; End-to-end implementation of process data analytics workflows; Software implementation using MATLAB and Python; Development of soft sensors and predictive models; Process monitoring, control, and optimization case studies using simulation and data analytics tools; Interpretation of results and decision-making in industrial contexts.

	Description of CO	PO	PSO1	PSO2
CO1	Explain the fundamentals of data analytics and exploratory data analysis for process industry applications.	-	3	2
CO2	Analyze different types of process data and their sources used in process industries.	PO1(3) PO2(1)	1	2
CO3	Apply data-based modelling techniques to develop predictive models for industrial processes.	PO2(2) PO3(1)	3	1
CO4	Evaluate data-driven modelling approaches for effective process control.	PO1(2) PO2(2)	2	2
CO5	Optimize process performance using data analytics and optimization techniques.	PO3(1)	1	1

References:

1. Daniela Galatro, Stephen Dawe (2024) "Data Analytics for Process Engineers", 1st edition, Springer, 2024.
2. Roger Peng (2016) "Exploratory Data Analysis with R", 1st edition.
3. Beheshti, S., Benatallah, B., Sakr, S., Grigori, D., MotahariNezhad, H. R., Barukh, M. C., Gate r, A., Ryu, S. H. 2016 "Process Analytics: Concepts and Techniques for Querying and Analyzing Process Data" 1st edition, Springer.
4. Araghinejad, Shahab. 2013 "Data-Driven Modeling: Using MATLAB® in Water Resources and Environmental Engineering" 1st edition, Springer.
5. K. Murphy, 2012 "Machine Learning: A Probabilistic Perspective", Illustrated edition, MIT Press,