Malaviya National Institute of Technology Jaipur

Proposed Curriculum of M. Tech. in Chemical Engineering

Proposed M. Tech. Program Name: Chemical Engineering and Sustainability

M. Tech I Semester (Chemical Engineering and Sustainability)

S. No	Course Code	Course Title	Category	Type	Credit	L	T	P
1.	25CHT521	Transport Analysis	PC	Theory	4	3	0	2
2.	25CHT522	Advanced Reaction Engineering	PC	Theory	4	3	0	2
3.	25CHT523	Life Cycle Assessment of Chemical Processes	PC	Theory	4	3	0	2
4.	25CHT524	Sustainable Separation Processes	PC	Theory	4	3	0	2
5.	25CHT525	Advanced Material Characterization	PC	Theory	2	1	0	2
				Total Credits	18			

M. Tech. II Semester (Chemical Engineering and Sustainability)

(Any four subjects to be registered)

S. No	Course Code	Course Title	Category	Type	Credit	L	T	P
1.	25CHT801	Sustainable Solid Waste Management	PE	Theory	4	3	0	2
2.	25CHT802	Carbon Management and Upcycling	PE	Theory	4	3	0	2
3.	25CHT803	Hydrogen and Fuel Cell Technologies	PE	Theory	4	3	0	2
4.	25CHT804	Sustainable Process Design: Modeling and Simulation	PE	Theory	4	3	0	2
5.	25CHT805	Computational Methods for Sustainable Processes	PE	Theory	4	3	0	2
6.	25CHT806	Process Integration and Intensification	PE	Theory	4	3	0	2
7.	25CHT807	Process Safety and hazard Management	PE	Theory	4	3	0	2
8.	25CHT808	Biochemical Engineering	PE	Theory	4	3	0	2
9.	25CHT809	Statistical Methods	PE	Theory	4	3	0	2
10.	25CHT810	AI & ML in Process Engineering	PE	Theory	4	3	0	2
11.	25CHT811	Advanced Thermodynamics	PE	Theory	4	3	0	2
12.	25CHT812	Clean Technologies for Pollution Control	PE	Theory	4	3	0	2
13.	25CHT813	Catalysis Science and Technology	PE	Theory	4	3	0	2
				Total Credits	16			

M. Tech. III Semester (Chemical Engineering and Sustainability)

S. No.	Course Code	Course Title	Category	Type	Credit	L	T	P
1.	25CHD621	Dissertation-I	PC	-	12	-	-	-

M. Tech. IV Semester (Chemical Engineering and Sustainability)

S. No.	Course Code	Course Title	Category	Type	Credit	L	T	P
1.	25CHD622	Dissertation-II	PC	Theory	12	-	-	-

L=Lecture hours/week P=Practical hours/week T=Tutorial hours/week

PC= Program Core PE= Program Elective

Two hours practical in each course may comprise extended industry oriented discussion, hands on practice, field visit, projects to customize and enrich the industry skills, learning experience which inculcate additional opportunities to the students to get experience in emerging trends and technologies.

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT521	Transport Analysis	4	3	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

To impart knowledge about momentum, heat and mass transport, model development along with appropriate boundary conditions.

COURSE OUTCOMES

CO1	Transform practical problems into mathematical equations for momentum, heat and mass transport.
CO2	Recognize and apply analogies between momentum, heat, and mass transfer on both microscopic and macroscopic levels.
CO3	Formulate mathematical models to represent complex transport phenomena in different geometries and solve differential equations for various transport phenomena problems.

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following four components:

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Introduction: Conservation laws and analogy between transport of momentum, thermal energy and mass of species, Basic concepts and review of classical flow problems, Mathematical foundations, boundary conditions. Vector and tensor.

(No. of lectures- 6)

Unit II- Momentum transport: Basic equations of momentum transport in isothermal flow system, shell momentum balance, Equations of change for isothermal systems–Navier-Stokes equation, Velocity distributions with more than one independent variable: unsteady viscous flow.

(No. of lectures- 12)

Unit III- Energy transport: Review of fundamentals and classical conduction problems, shell energy balance, Temperature distribution with more than one independent variable: unsteady heat conduction in solids. The equations of change for non-isothermal systems. Macroscopic balances for non-isothermal systems: power requirement for pumping of a compressible fluid through a long pipe. Heating of a liquid in an agitated tank.

(No. of lectures- 10)

Unit IV Mass transport: Review of classical mass transfer problems and basic equations for diffusion mass transport in binary systems. Concentration distribution in solids and in laminar flow: diffusion with homogeneous chemical reaction, gas absorption with chemical, reaction in an agitated tank.

(No. of lectures- 7)

Unit V- Coupled transport processes: forced convection heat and mass transport in confined/unconfined flows. Heat, mass and momentum transfer in multi-component systems, Turbulence modeling.

(No. of lectures- 5)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Bird, R. B., Stewart, W. E. and Lightfoot, E. N., Transport Phenomena, 2nd Ed., Wiley, 2006.
2. Batchelor, G. K., An Introduction to Fluid Dynamics, 2nd Ed., Cambridge University Press, Cambridge, 2002.
3. Slattery, J. C., Momentum, Energy and Mass Transfer in Continua, Robert E. Krieger Publishing Company, New York, 1981.
4. Geankoplis, C. J., Transport Processes and Separation Process Principles, 4th Ed., PHI, New Delhi, 2011.
5. V. Kumaran, Fundamentals of Transport Processes with Applications, Cambridge IISc Series, 2022.

LECTURE PLAN

Lecture No.	Topics to be covered
1.	Introduction of transport phenomena (momentum, heat, mass), Continuum hypothesis and conservation laws.
2.	Analogy between transport of momentum, heat and mass of species, Flux and driving force in transport processes,
3.	Common examples of the importance of modeling of transport of heat, mass and momentum – fluidized bed reactor.
4.	Representation of vectors and tensors using index notations
5.	Tensor calculus, gradient, Laplacian and divergence of vectors and tensors
6.	Constitutive relations
7.	Introduction to momentum transfer
8.	Laminar and turbulent flows; Boundary layer
9.	Pipe flow – entrance region, boundary layer formation, potential core. Flow of two immiscible fluids, velocity and stress continuity,
10.	Linear momentum balance (Navier-Stokes equation NSE), Two extreme cases of NSE - Potential flow (inviscid) and creeping flow (viscous flow).
11.	Momentum fluxes – viscous flux and convective flux; Representation of viscous and convective momentum fluxes in terms of the Components.
12.	Introduction to shell momentum balance; Flow through circular pipe- Solution of velocity profile using the shell momentum balance; Discussion on boundary conditions to obtain the constants of integration; Sketches of velocity profile; Mathematical expression for volumetric flow rate and average velocity.
13.	Flow of film falling over an inclined plane
14.	Pressure and plate driven flow between two flat plates

15.	Flow of two immiscible liquids between parallel plates- Sketches of velocity profile for different viscosity stratifications
16.	Basics of coordinate systems – Cartesian, cylindrical and spherical coordinates.
17.	Flow due to rod moving in a circular cylinder
18.	Flow through vertical pipe – combining pressure and gravity as modified pressure, Taylor-Couette flow – flow between two concentric cylinders with one cylinder rotating and other stationary,
19.	Heat transfer – Modes of heat transfer; Heat conduction through solids; Conductive heat flux; Fourier law of heat conduction; shell energy balance to obtain steady-state temperature profile.
20.	Heat conduction through a slab– shell energy balance with uniform heat source, temperature profile in slab, Estimation of rate of heat transfer.
21.	Conduction through composite slabs, temperature-dependent thermal conductivity;
22.	Heat transfer through single slab open to air - Dirichlet and Neumann boundary conditions, Newton's law of cooling and heat transfer coefficient,
23.	Heat transfer from an insulated pipe to surrounding,
24.	Heat transfer from a cylindrical fin,
25.	fin efficiency, Biot number and Nusselt number;
26.	Introduction of the equation for thermal energy balance – meaning of all terms including conduction, convection and viscous dissipation
27.	Heat transfer in flow through pipe
28.	The equations of change for non-isothermal systems.
29.	Macroscopic balances for non-isothermal systems: power requirement for pumping of a compressible fluid through a long pipe.
30.	Introduction to mass transfer, Fick's law and multicomponent diffusion
31.	Concept of mass transfer coefficient, Mass transfer in laminar flow, Sherwood number, Schmidt number
32.	Mass transfer in chemical reactions and porous media,
33.	Heterogeneous catalytic reaction – external mass transfer through film, internal pore diffusion with chemical reaction
34.	External mass transfer within a flat film with instantaneous reaction at the catalyst surface
35.	External mass transfer within a flat film with a slow reaction at the catalyst surface
36.	Simultaneous heat, mass, and momentum transfer in confined/unconfined flows
37.	Heat, mass and momentum transfer in multi-component systems
38.	Non-Newtonian fluid flow
39.	Transport in biological systems or microfluidics
40.	Turbulence modeling.

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT522	Advanced Reaction Engineering	4	3	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

To provide comprehensive knowledge of catalysis, reactor design and their application in the petroleum industry.

COURSE OUTCOMES

CO1	Use the principles of reaction engineering for design and analysis of reactors
CO2	Analyze and interpret data from catalytic experiments
CO3	Apply knowledge of catalysis to solve real-world engineering problems.

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following four components;

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Introduction: Introduction of various reactors (BR, CSTR, PFR, MBR), Non-isothermal steady state reactor design, Energy balance, Pressure drop in reactor design (PBR), Multiple steady states.

(No. of lectures- 6)

Unit II- Fundamentals of Catalysis: Homogeneous and Heterogeneous Catalysis, Preparation methods, Steps in catalytic reaction, Analysis of external transport processes in heterogeneous reactions in fixed bed, fluidized bed and slurry reactors. Intrapellet mass transfer, heat transfer, mass transfer with chemical reaction and simultaneous mass and heat transfer with chemical reaction

(No. of lectures- 8)

Unit III- Catalyst Deactivation: Modes of deactivation – poisoning, fouling and sintering. Determination of deactivation routes, combined effect of deactivation and diffusion on reaction rates, effect of deactivation on selectivity.

(No. of lectures-6)

Unit IV Reactor Design: Design calculation for ideal catalytic reactor operating at isothermal, adiabatic and non-adiabatic conditions. Deviations from ideal reactor performance. Design of industrial fixed-bed, fluidized bed and slurry reactors. Thermal stability of packed bed and fluidized bed reactors.

(No. of lectures- 8)

Unit V- Polymeric Reactions: Introduction to polymeric reactions and their kinetics, rate of polymerization, types of polymerization, reactors for polymerization reactions

(No. of lectures- 8)

Unit VI- Case Studies: Industrial reactors and case studies

(No. of lectures- 4)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Levenspil, O., Chemical Reaction Engineering-An Indian Adaptation, John Wiley & Sons, 2020
2. Scott Fogler, H., Essentials of Chemical Reaction Engineering, Pearson, 2020
3. Hill, C. G.; Root, T. W. An Introduction to Chemical Engineering Kinetics & Reactor Design, John Wiley & Sons, 2014
4. Asua, J. M. Polymer Reaction Engineering, Blackwell Publishing Ltd., 2007
5. Smith, J. M., Chemical Engineering Kinetics, Mcgraw Hill, 1981

LECTURE PLAN

Lecture No.	Topics to be covered
1.	Introduction of various reactors (BR, CSTR)
2.	Introduction of various reactors (PFR, MBR)
3.	Non-isothermal steady state reactor design
4.	Energy balance calculations
5.	Pressure drop in reactor design (PBR),
6.	Multiple steady states.
7.	Homogeneous and heterogeneous catalysis
8.	Catalyst preparation methods
9.	Steps in catalytic reaction
10.	External transport processes in heterogeneous reactions in fixed bed reactors
11.	External transport processes in heterogeneous reactions in fluidized bed and slurry reactors
12.	Intrapellet mass transfer and heat transfer
13.	Mass transfer with chemical reaction
14.	Simultaneous mass and heat transfer with chemical reaction.
15.	Modes of deactivation – poisoning, fouling and sintering-I
16.	Modes of deactivation – poisoning, fouling and sintering-II
17.	Determination of deactivation routes
18.	The combined effect of deactivation and diffusion on reaction rates-I
19.	The combined effect of deactivation and diffusion on reaction rates-II
20.	Effect of deactivation on selectivity
21.	Design calculation for ideal catalytic reactor operating at isothermal conditions
22.	Design calculation for ideal catalytic reactor operating at adiabatic conditions

23.	Design calculation for ideal catalytic reactor operating at non-adiabatic conditions
24.	Deviations from ideal reactor performance
25.	Design of industrial fixed-bed reactors
26.	Design of industrial fluidized bed reactors.
27.	Design of industrial slurry reactors.
28.	Thermal stability of packed bed and fluidized bed reactors.
29.	Introduction to polymeric reactions and their kinetics-I
30.	Introduction to polymeric reactions and their kinetics-II
31.	Rate of polymerization reactions
32.	Types of polymerization reactions-I
33.	Types of polymerization reactions-II
34.	Reactors for polymerization reactions
35.	Reactors for polymerization reactions-I
36.	Reactors for polymerization reactions-II
37.	Industrial reactors
38.	Case studies-I
39.	Case studies-II
40.	Case studies-III

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT523	Life Cycle Assessment of Chemical Processes	4	3	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

To promoting sustainable practices thorough understanding of Life Cycle Assessment.

COURSE OUTCOMES:

CO1	Evaluate the environmental footprint of various systems, technologies, and products.
CO2	Perform comprehensive LCA assessments using contemporary software tools.
CO3	Apply knowledge in circularity to promote sustainable practices in engineering projects.

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following four components;

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- LCA methodologies, Data requirements and data sources for LCA, LCA frameworks; Life Cycle Inventory (LCI), Life Cycle Impact Assessment (LCIA), Interpretation of LCA results, Uncertainty and Sensitivity analysis

(No. of lectures- 6)

Unit II- LCA for Chemical processes and products, Design and principle for sustainability, LCA on renewable energy, The Availability of Suitable Datasets for the LCA Analysis of Chemical Substances.

(No. of lectures- 8)

Unit III- Comparison of the LCIA Methods Used for the Evaluation of Chemicals, LCA Integration Within Sustainability Metrics for Chemical Companies, The LCA Modelling of Chemical Companies in the Industrial Symbiosis Perspective: Allocation Approaches and Regulatory Framework.

(No. of lectures- 11)

Unit IV- Application of LCA in Chemicals Process Modelling: LCA Application to Chemical Synthesis at Laboratory Scale, LCA as a Support Tool for the Evaluation of Industrial Scale-Up.

(No. of lectures- 8)

Unit V- Case Studies of LCA: Phosphate Recovery, Wastewater Cycle Management, Petroleum Industry, Municipal Solid Waste Management, Different Fertilizer Products.

(No. of lectures- 8)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Life Cycle Assessment: Principles, Practice, and Prospects by Olivier Jolliet,Myriam Saadé-Sbeih, and Shanna Shaked, 2015.
2. Life Cycle Assessment Handbook: A Guide for Environmentally Sustainable Products by Mary Ann Curran, 2012.
3. Life Cycle Assessment in the Chemical Product Chain: Challenges, Methodological Approaches and Applications by Simone Maranghi and Carlo Brondi, Springer, 2020.
4. Life cycle assessment (LCA) of different fertilizer product types, K. Hasler, S. Bröring, S.W.F. Omta, H.-W. Olfs, Elsevier (Article), 2015.
5. Life cycle assessment in the petroleum industry: A systematic framework towards improved environmental performance, Huda Majid Al Zarkani, Toufic Mezher, Mutasem El-Fadel, Elsevier (Article), 2023.

LECTURE PLAN

Lecture No.	Topics to be covered
1.	LCA methodologies
2.	Data requirements and data sources for LCA
3.	LCA frameworks, Life Cycle Inventory (LCI)
4.	Life Cycle Impact Assessment (LCIA)
5.	Interpretation of LCA results
6.	Uncertainty and Sensitivity analysis
7.	LCA for Chemical processes and products
8.	LCA for Chemical processes and products, cont..
9.	Design and principle for sustainability
10.	Design and principle for sustainability, cont..
11.	LCA on renewable energy
12.	LCA on renewable energy, cont..
13.	The Availability of Suitable Datasets for the LCA Analysis of Chemical Substances
14.	The Availability of Suitable Datasets for the LCA Analysis of Chemical Substances, cont..
15.	Comparison of the LCIA Methods Used for the Evaluation of Chemicals
16.	Comparison of the LCIA Methods Used for the Evaluation of Chemicals, cont..
17.	Comparison of the LCIA Methods Used for the Evaluation of Chemicals, cont..
18.	LCA Integration Within Sustainability Metrics for Chemical Companies
19.	LCA Integration Within Sustainability Metrics for Chemical Companies, cont..
20.	LCA Integration Within Sustainability Metrics for Chemical Companies, cont..
21.	The LCA Modelling of Chemical Companies in the Industrial Symbiosis Perspective: Allocation Approaches and Regulatory Framework.
22.	The LCA Modelling of Chemical Companies in the Industrial Symbiosis Perspective: Allocation Approaches and Regulatory Framework, cont..

23.	The LCA Modelling of Chemical Companies in the Industrial Symbiosis Perspective: Allocation Approaches and Regulatory Framework, cont..
24.	The LCA Modelling of Chemical Companies in the Industrial Symbiosis Perspective: Allocation Approaches and Regulatory Framework, cont..
25.	Application of LCA in Chemicals Process Modelling
26.	Application of LCA in Chemicals Process Modelling, cont..
27.	LCA Application to Chemical Synthesis at Laboratory Scale
28.	LCA Application to Chemical Synthesis at Laboratory Scale, cont..
29.	LCA Application to Chemical Synthesis at Laboratory Scale, cont..
30.	LCA as a Support Tool for the Evaluation of Industrial Scale-Up
31.	LCA as a Support Tool for the Evaluation of Industrial Scale-Up, cont..
32.	LCA as a Support Tool for the Evaluation of Industrial Scale-Up, cont..
33.	Case Studies of LCA: Phosphate Recovery
34.	Case Studies of LCA: Wastewater Cycle Management
35.	Case Studies of LCA: Wastewater Cycle Management, cont..
36.	Case Studies of LCA: Petroleum Industry
37.	Case Studies of LCA: Petroleum Industry, cont..
38.	Case Studies of LCA: Municipal Solid Waste Management
39.	Case Studies of LCA: Municipal Solid Waste Management, cont..
40.	Case Studies of LCA: Different Fertilizer Products

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT524	Sustainable Separation Processes	4	3	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

To learn concept and design aspects of advanced and innovative separation techniques.

COURSE OUTCOMES

CO1	Gain knowledge to select a suitable separation technique for separation of product mixture.
CO2	Understated the concept of membrane-based separation technique.
CO3	Understand the ion exchange and other advanced separation techniques.

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following four components;

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Introduction: Separation process in chemical and Biochemical Industries, Categorization of separation processes, equilibrium and rate governed processes.

(No. of lectures- 10)

Unit II- Membrane based Separation Technique (MBSTs): Historical background, physical and chemical properties of membranes, Techniques of membrane preparation, membrane characterization, various types of membranes and modules. Osmosis and osmotic pressure. Working principle, operation and design of Reverse osmosis, Ultrafiltration, Microfiltration, Nano-filtration, Electrodialysis and Pervaporation. Gas separation by membranes and liquid membranes.

(No. of lectures- 12)

Unit III- Ion Exchange: History, basic principle and mechanism of separation, Ion exchange resins, regeneration and exchange capacity. Exchange equilibrium, affinity, selectivity and kinetics of ion exchange. Design of ion- exchange systems and their uses in the removal of ionic impurities from effluents.

(No. of lectures- 10)

Unit IV Innovation in separation techniques: Reactive distillation, supercritical fluid extraction, chromatographic separation. Pressure and temperature swing adsorption, Dividing-wall columns (DWCs), integrated separation processes etc.

(No. of lectures- 8)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. J.D. Seader, Ernest J. Henley, "Separation Process Principles" 2nd Ed., Wiley India Pvt. Ltd. 2006
2. Marcel Mulder, Basic Principles of Membrane Technology, 2nd Ed., Springer 1996
3. B K Dutta, Principles of Mass Transfer and Separation Processes, PHI Learning. 2007
4. McHugh, M. A. and Krukonis, V. J., "Supercritical Fluid Extraction", Butterworths, Boston. 1985
5. Sourirajan, S. and Matsura, T., "Reverse Osmosis and Ultra-filtration – Process Principles," NRC Publications, Ottawa. 1985.

Lecture Plan

Lecture No.	Topics to be covered
1.	Separation process in chemical and Biochemical Industries, Classification of separation techniques
2.	Criteria for selecting a separation process, Overview: Physical vs. chemical vs. biological separations
3.	Phase Equilibria and Thermodynamics, Importance of phase diagrams in separation design, Thermodynamic feasibility of separations
4.	Equilibrium and rate governed processes
5.	Distillation – Fundamentals and Applications
6.	Absorption and Stripping
7.	Liquid-Liquid Extraction, Drying and Evaporation
8.	Centrifugation and Sedimentation
9.	Integration of Separation Processes, Hybrid and multi-stage separations,
10.	Introduction to Sustainable Separation, Definition of sustainability in chemical engineering, Importance of separation processes
11.	Membrane based Separation Technique (MBSTs): Historical background and Classification of membranes
12.	Membrane Materials and Fabrication, Desirable membrane properties
13.	Fabrication techniques: phase inversion, stretching, sintering, coating, Recent advances in membrane materials
14.	Detailed discussion on microfiltration
15.	Ultrafiltration
16.	Applications in water treatment and food processing.
17.	Nanofiltration
18.	Reverse Osmosis- Principles, applications, and limitations.
19.	Introduction to electrodialysis and dialysis, Use in desalination and medical applications.
20.	Gas separation by membranes and liquid membranes

21.	Membrane Fouling and Membrane Cleaning Techniques
22.	Membrane Module Design and Configurations
23.	Fundamental principles of ion exchange processes, Development and use of ion exchange in various industries
24.	Types of Ion Exchange, Importance of ion exchange in water treatment, pharmaceuticals, and food industries.
25.	Ion Exchange Reactions
26.	Ion Exchange Resin
27.	Regeneration and Recovery of Resins
28.	Equilibrium and kinetics of ion exchange, Factors influencing ion exchange efficiency (temperature, concentration gradients, etc.)
29.	Ion Exchange Equilibrium and Selectivity
30.	Design of ion- exchange systems and their uses in the removal of ionic impurities from effluents.
31.	Environmental Impact and Sustainability of Ion Exchange
32.	Advances in Ion Exchange Technology
33.	Innovation in separation techniques
34.	Reactive distillation, supercritical fluid extraction,
35.	Hybrid Membrane Filtration and Adsorption
36.	Dividing-wall columns (DWCs),
37.	Pressure and temperature swing adsorption,
38.	Supercritical Fluid Chromatography
39.	Integrated separation processes
40.	Emerging Hybrid Separation Techniques

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT525	Advanced Material Characterization	2	1	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

To introduce students to the principles and applications of material characterization techniques.

COURSE OUTCOMES

CO1	Apply appropriate characterization techniques for structure and compositional analysis of materials.
CO2	Select suitable techniques for morphology and microstructure investigation.
CO3	Analyze the crystal structure of a given material using diffraction data and assess thermal stability and thermodynamic transitions of materials

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following four components;

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Introduction: Introduction to materials, Materials classifications, Physical and chemical properties of materials, Introduction to characterization methods.

(No. of lectures- 2)

Unit II- Spectroscopy techniques: Infrared spectroscopy, Molecular vibration analysis, Chemical bonds identification, RAMAN, Structural information and Defect analysis; X-Ray photoelectron spectroscopy (XPS), Applications, Surface analysis, Binding energy measurements, Chemical state analysis.

Diffraction techniques: X-ray Diffraction (XRD), Bragg's law, Phase identification, Crystal structure analysis.

(No. of lectures- 3)

Unit III- Morphology analysis: Scanning electron microscopy (SEM), Transmission electron microscopes (TEM), Atomic force microscopy (AFM), Principle, Types of detectors, Sample preparation, Application in materials science.

(No. of lectures- 4)

Unit IV Surface area and pore analysis: BET, Chemisorptionon, Temperature programmed desorption, Temperature programmed reduction, Principle, Applications, Analysis.

(No. of lectures- 3)

Unit V- Thermal characterization techniques: Thermogravimetric analysis (TGA); Mass change as a Function of temperature, Oxidation, Decomposition; Differential scanning calorimetry (DSC); Heat flow, Glass transition, Crystallization, and Melting, Applications

(No. of lectures- 3)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. S Lowell, Joan E. Shields, Martin A. Thomas, and Characterization of porous solids and powders: Surface Area, Pore Size and Density – Springer, 2006.
2. Sam Zhang, Lin Li, Ashok Kumar, Materials Characterization Techniques, CRC Press, 2009.
3. R.E. Dinnerbier and S. L. J. Billinge, Powder Diffraction: Theory and Practice, RSC Publishing, 2008.
4. M.E.Brown , Introduction to thermal analysis : Techniques and application , second edition, Springer, 2007
5. E.N. Kaufmann (Ed), Characterization of Materials, Wiley –Inter Science, 2003
6. W.D.Callister (Jr.), Material Science and Engineering:An Introduction, 8th Ed. John Wiley & Sons, 2010.

LECTURE PLAN

Lecture No.	Topics to be covered
1.	Introduction: Introduction to materials, Materials classifications
2.	Physical and chemical properties of materials, Introduction to characterization methods
3.	Spectroscopy techniques: Infrared spectroscopy, Molecular vibration analysis
4.	Molecular vibration analysis, Chemical bonds identification, RAMAN, Structural information and Defect analysis
5	X-Ray photoelectron spectroscopy (XPS), Applications, Surface analysis, Binding energy measurements, Chemical state analysis
6	Morphology analysis: Scanning electron microscopy (SEM)
7	Transmission electron microscopes (TEM)
8	Atomic force microscopy (AFM)
9	Principle, Types of detectors, Sample preparation, Application in materials science
10	Surface area and pore analysis: BET, Chemisorptionon
11	Temperature programmed desorption
12	Temperature programmed reduction, Principle, Applications, Analysis
13	Thermal characterization techniques Thermogravimetric analysis (TGA)
14	Mass change as a Function of temperature, Oxidation, Decomposition
15	Differential scanning calorimetry (DSC); Heat flow, Glass transition, Crystallization, and Melting, Applications

M. Tech II Semester (Chemical Engineering and Sustainability)

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT801	Sustainable Solid Waste Management	4	3	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

To introduce students to the concepts of sustainable waste management and the importance of adhering to environmental regulations.

COURSE OUTCOMES

CO1	Understand the importance of integrated waste management and environmental regulations.
CO2	Classify different types of waste and their characteristics.
CO3	Apply knowledge in municipal solid waste, hazardous waste, plastic waste, and e-waste management and analyze the physical, chemical, and biological properties of waste.

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following four components;

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Introduction: Sustainable waste management importance, Types of wastes, Waste hierarchy and Circular economy.

(No. of lectures- 6)

Unit II- Waste Collection, characterization and quantification; Waste collection, handling, separation, storage, transfer and processing of solid waste, Identification and Segregation of hazardous and nonhazardous wastes, Health and safety consideration in waste handling, Characterization Methods (Physical. Chemical, Biological properties). Mass change as a Function of temperature, Oxidation, Decomposition Global and national waste management laws, regulations, codes, Role of government, industry, and communities in waste management.

(No. of lectures- 10)

Unit III- Waste treatment process; Physical methods**,** Chemical methods, Biological methods, Thermal methods, Advanced Techniques (Hydrothermal, etc.), Recycling and resource recovery from electronic wastes, battery wastes, heavy metal containing spent catalysts, spent caustic and tannery wastes.

(No. of lectures- 8)

Unit IV- Landfill design and management: Landfill site selection and design, Landfill liners, leachate collection and gas management, Landfill closure and post-closure care, Remediation of hazardous waste landfill.

(No. of lectures- 8)

Unit V- Case Studies: Case studies on industrial wastes (oil refinery/fertilizer/ sugar/paper industries,/tannery, medical waste, and laboratory chemical waste etc.), E-waste; Spent catalysts management, etc.

(No. of lectures- 8)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):

1. Tchobanglais G., Theisen H. and Vigil S.A., “Integrated Solid Waste Management: Engineering Principles and Management Issues”, McGraw Hill, 1993.
2. Conway R.A. and Ross R.D., “Handbook of Industrial Waste Disposal”, Van-Nostrand Reinhold, 1980.
3. Pichtel J., “Waste Management Practices: Municipal, Hazardous and Industrial”, CRC Press, 2014.
4. Shah K.L., “Basics of Solid and Hazardous Waste Management Techniques”, Prentice Hall, 1999.
5. Tedder D.W. and Pohland F.G. (editors), “Emerging Technologies in Hazardous Waste Management”, American Chemical Society, 2007.

LECTURE PLAN

Lecture No.	Topics to be covered
1 & 2	Introduction: Sustainable waste management importance
3 & 4	Types of wastes
5 & 6	Waste hierarchy and Circular economy
7 & 8	Waste Collection, characterization and quantification; Waste collection, handling, separation, storage, transfer and processing of solid waste,
9 & 10	Identification and Segregation of hazardous and nonhazardous wastes,
11	Health and safety consideration in waste handling,
12 & 13	Characterization Methods (Physical. Chemical, Biological properties).
14 & 15	Solid Waste management regulations and policies; Global and national waste management laws, regulations, codes,
16	Role of government, industry, and communities in waste management.
17	Waste treatment process; Physical methods
18	Chemical methods
19	Biological methods
20	Thermal methods
21	Advanced Techniques (Hydrothermal, etc.)
22 & 23	Recycling and resource recovery from electronic wastes, battery wastes, heavy metal containing spent catalysts, spent caustic and tannery wastes.

24 & 25	Landfill design and management: Landfill site selection and design
26 & 27	Landfill liners, leachate collection and gas management
28 & 29	Landfill closure and post-closure care
30 & 31	Remediation of hazardous waste landfill
32	Case Studies: Case studies on industrial wastes (oil refinery)
33	Fertilizer
34	Sugar
35	paper industries
36	tannery,
37	medical waste, laboratory chemical waste
38	laboratory chemical waste
39	E-waste;
40	Spent catalysts management.

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT802	Carbon Management and Upcycling	4	3	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

Gain a thorough understanding of advanced carbon management techniques and innovative approaches for reducing carbon emissions.

COURSE OUTCOMES

CO1	Knowledge of advanced methods and new ideas to reduce carbon emissions.
CO2	Learn science-based goals and create effective plans and policies for carbon management.
CO3	Apply practical knowledge from real-life examples to improve carbon management practices.

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following four components;

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Carbon Foot printing: Understanding Greenhouse Gas Management: scopes and boundaries for carbon foot printing, Carbon Accounting, Strategy, Policies and Practices for Carbon Management.

(No. of lectures- 8)

Unit II- Carbon Capture Technologies: CO_2 capture by absorption and adsorption, Membrane for CO_2 separation, Chemical looping combustion for inherent CO_2 capture, CO_2 capture using nanomaterials

(No. of lectures- 8)

Unit III- CO_2 Storage and Transportation: Geological Storage, Ocean Storage, Mineral Carbonation.

(No. of lectures- 5)

Unit IV- CO_2 Utilization: Biochar: Carbon Negative Technology for Combating Climate Change, Progresses in Bioenergy Generation from CO_2: Mitigating the Climate Change, Catalytic processes for fuels production from CO_2-rich streams (Opportunities for industrial flue gases upgrading), Industrial processes emitting CO_2-rich streams.

(No. of lectures- 11)

Unit V- Case Studies: Methanation of unconventional flue gases, Biogas dry reforming for syngas production from CO_2, Valorization of unconventional CO_2-rich feedstock via Reverse Water Gas Shift reaction.

(No. of lectures- 8)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Baena, F. M., Arias, J. G., Reina, T.R., Pérez, L. P., "Circular Economy Processes for CO2 Capture and Utilization: Strategies and Case Studies", Elsevier, 2023.
2. Pant, D., Nadda, A. K., Pant, K. K., Agarwal, A. K., "Advances in Carbon Capture and Utilization", Springer, 2021.
3. Kuckshinrichs, W., Hake, J. F., "Carbon Capture, Storage and Use Technical, Economic, Environmental and Societal Perspectives", Springer, 2015.
4. Hill, P. M., Winfield, F., Howarth, R., Mazhar, M., "The Handbook of Carbon Management: A Step-by-Step Guide to High-Impact Climate Solutions for Every Manager in Every Function", Routledge: Taylor and Francis Group, 2023.
5. Khalid, M., Dharsakar, S. A., Sillanpää, M., Siddiqui, H., Emerging Carbon Capture Technologies Towards a Sustainable Future, Elsevier, 2022.

LECTURE PLAN

Lecture No.	Topics to be covered
1.	Understanding Greenhouse Gas Management: scopes and boundaries for carbon foot printing
2.	Understanding Greenhouse Gas Management: scopes and boundaries for carbon foot printing, cont
3.	Understanding Greenhouse Gas Management: scopes and boundaries for carbon foot printing, cont..
4.	Carbon Accounting
5.	Carbon Accounting, cont..
6.	Strategy, Policies and Practices for Carbon Management
7.	Strategy, Policies and Practices for Carbon Management, cont..
8.	Strategy, Policies and Practices for Carbon Management, cont..
9.	Carbon Capture Technologies: Introduction
10.	CO_2 capture by absorption and adsorption
11.	CO_2 capture by absorption and adsorption, cont..
12.	Membrane for CO_2 separation
13.	Membrane for CO_2 separation, cont..
14.	Chemical looping combustion for inherent CO_2 capture
15.	Chemical looping combustion for inherent CO_2 capture, cont..
16.	CO_2 capture using nanomaterials
17.	CO_2 Storage and Transportation: Overall strategy
18.	CO_2 Storage and Transportation: Overall strategy, cont..
19.	Geological Storage
20.	Ocean Storage
21.	Mineral Carbonation

22.	CO_2 Utilization: Introduction
23.	Biochar: Carbon Negative Technology for Combating Climate Change
24.	Biochar: Carbon Negative Technology for Combating Climate Change, cont..
25.	Biochar: Carbon Negative Technology for Combating Climate Change, cont..
26.	Progresses in Bioenergy Generation from CO_2: Mitigating the Climate Change
27.	Progresses in Bioenergy Generation from CO_2: Mitigating the Climate Change, cont..
28.	Catalytic processes for fuels production from CO_2-rich streams (Opportunities for industrial flue gases upgrading)
29.	Catalytic processes for fuels production from CO_2-rich streams (Opportunities for industrial flue gases upgrading), cont..
30.	Catalytic processes for fuels production from CO_2-rich streams (Opportunities for industrial flue gases upgrading), cont..
31.	Industrial processes emitting CO_2-rich streams
32.	Industrial processes emitting CO_2-rich streams, cont..
33.	Methanation of unconventional flue gases
34.	Methanation of unconventional flue gases, cont..
35.	Biogas dry reforming for syngas production from CO_2
36.	Biogas dry reforming for syngas production from CO_2, cont..
37.	Biogas dry reforming for syngas production from CO_2, cont..
38.	Valorization of unconventional CO_2-rich feedstock via Reverse Water Gas Shift reaction
39.	Valorization of unconventional CO_2-rich feedstock via Reverse Water Gas Shift reaction, cont..
40.	Valorization of unconventional CO_2-rich feedstock via Reverse Water Gas Shift reaction, cont..

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT803	Hydrogen and Fuel Cell Technologies	4	3	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

To gain insight about hydrogen energy, fuel cells, their working principle, types of fuel cells and performance analysis.

COURSE OUTCOMES

CO1	Gain knowledge on hydrogen production, storage technologies and economic aspects.
CO2	Gain knowledge on fuel cell working principle, types of fuel cell, voltage loss and its reason.
CO3	Understand the role of fluid dynamics, reaction kinetics and mass transfer principles in fuel cell operation. Stacking of fuel cell and fuel processing for fuel cell.

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following four components;

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Introduction to hydrogen energy systems: Current scenario of hydrogen production, Hydrogen production pathways**:** Thermal, Gasification, Electrochemical, and Biological, Infrastructure requirement for hydrogen production, dispensing and utilization.

(No. of lectures- 8)

Unit II- Hydrogen Storage and Utilization: General storage methods, compressed storage, Zeolites, Metal hydride storage, chemical hydride storage and cryogenic storage. Utilization in fuel cells, IC engines, Gas turbines, refineries etc.

(No. of lectures- 8)

Unit III- Introduction to Fuel Cell: Fuel cell advantages, fuel cell disadvantages, fuel cell performance characterization and modeling, fuel cell technology, Fuel Cell Types**,** Phosphoric acid fuel cell, polymer electrolyte membrane fuel cell, alkaline fuel cell, molten carbonate fuel cell, solid-oxide fuel cell.

(No. of lectures- 8)

Unit IV- Charge and Mass Transport in Fuel Cell: Charges movement, Voltage loss, characteristics of charge transport resistance, conductivity. Mass Transport in electrode versus flow structure, transport in electrode: diffusive and convective transport.

(No. of lectures- 8)

Unit V- Thermodynamics and Reaction Kinetics in Fuel Cell: Heat potential: Work potential: Gibbs Free Energy, Reversible Voltage, activation energy of charge transfer reactions, rate of reaction at equilibrium: exchange current density, Galvani potential, Butler– Volmer equation, Improving kinetic performance, simplified activation kinetics: Tafel equation.

(No. of lectures- 8)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Fuel Cell Fundamentals (3rd Ed.) by O' Hayre, Ryan/ Colella, Whitney/ Cha, Suk-Won. Wiley Publications, 2016.
2. James Larminie and Andrew Dicks, Fuel Cell Systems Explained, 2nd Ed., John Wiley & Sons Inc, 2000.
3. Supramaniam Srinivasan, Fuel Cells: From Fundamentals to Applications, Springer, 2010.
4. Frano Barbir, PEM Fuel Cells Theory and Practice, Elsevier Academic Press, 2005.

LECTURE PLAN

Lecture No.	Topics to be covered
1.	Introduction to hydrogen energy systems
2.	Current scenario of hydrogen production
3.	Hydrogen production pathways**:** Thermal, Gasification, Electrochemical, and Biological
4.	Hydrogen production pathways**:** Thermal, Gasification, Electrochemical, and Biological, cont..
5.	Hydrogen production pathways**:** Thermal, Gasification, Electrochemical, and Biological, cont..
6.	Hydrogen production pathways**:** Thermal, Gasification, Electrochemical, and Biological, cont..
7.	Infrastructure requirement for hydrogen production, dispensing and utilization
8.	Infrastructure requirement for hydrogen production, dispensing and utilization, cont..
9.	General storage methods
10.	Compressed storage
11.	Zeolites
12.	Metal hydride storage
13.	Cryogenic storage
14.	Utilization in fuel cells, IC engines, Gas turbines, refineries etc.
15.	Utilization in fuel cells, IC engines, Gas turbines, refineries etc., cont..
16.	Utilization in fuel cells, IC engines, Gas turbines, refineries etc., cont..
17.	Fuel cell advantages, fuel cell disadvantages
18.	Fuel cell performance characterization and modeling

19.	Fuel cell technology
20.	Fuel Cell Types- Phosphoric acid fuel cell
21.	Fuel Cell Types- Polymer electrolyte membrane fuel cell
22.	Fuel Cell Types- Molten carbonate fuel cell
23.	Fuel Cell Types- Alkaline fuel cell
24.	Fuel Cell Types- Solid Oxide fuel cell
25.	Charges movement
26.	Voltage loss
27.	Characteristics of charge transport resistance
28.	Conductivity
29.	Mass Transport in electrode versus flow structure
30.	Mass Transport in electrode versus flow structure, cont..
31.	Transport in electrode: diffusive and convective transport
32.	Transport in electrode: diffusive and convective transport, cont..
33.	Heat potential, Work potential, Gibbs free energy
34.	Reversible voltage, activation energy of charge transfer reactions
35.	Rate of reaction at equilibrium: exchange current density
36.	Galvani potential
37.	Butler– Volmer equation
38.	Butler– Volmer equation, cont..
39.	Improving kinetic performance
40.	Simplified activation kinetics: Tafel equation.

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT804	Sustainable Process Design: Modeling and Simulation	4	3	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

To study the modeling and simulation techniques of chemical processes and develop the process simulation skills.

COURSE OUTCOMES

CO1	Analyze physical and chemical phenomena involved in various process. Develop mathematical models for various chemical processes.
CO2	Understand several mathematical techniques to solve and various simulation approaches.
CO3	Understand the artificial intelligence-based modelling.

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following four components;

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Introduction: Industrial usage of process modelling and simulation; Classification of models, Model building, Modelling difficulties, Degree-of-freedom analysis, Selection of design variables, Macroscopic mass, energy and momentum balances; incorporation of fluid thermodynamics, chemical equilibrium, reaction kinetics and feed/ product property estimation in mathematical models. Review of numerical techniques for solving steady state and unsteady state models.

(No. of lectures- 10)

Unit II- Model Development and Simulation: Lumped models of chemical process equipment like reactors, distillation, absorption, extraction columns, evaporators, and heat exchangers etc. Unsteady state lumped systems and dynamic simulation; Computer algorithms for numerical solution of steady state and unsteady state models. Microscopic balances for steady state and dynamic simulation; process modeling with dispersion; axial mixing; diffusion, etc.

(No. of lectures- 12)

Unit III- Simulation Approach: Sequential modular approach, Equation oriented approach, Partitioning and tearing, Use of process simulators for flow sheet simulation. Introduction to application of artificial intelligence-based modeling methods using Artificial Neural Networks, Fuzzy logic, etc.

(No. of lectures- 10)

Unit IV Case studies: Simulations of sustainable processes such as Divided-wall columns (DWC), bioethanol process, etc.

(No. of lectures- 8)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Luyben, W. L., "Process Modeling, Simulation and Control for Chemical Engineers," McGraw Hill. 1998
2. Himmelblau, D. M., & Bischoff, K. B., "Process analysis and simulation: Deterministic systems," John Wiley, New York. 1968
3. Ramirez, W.F., "Computational Methods for Process Simulation," 2ndEd., Butterworth-Heinemann. 1997
4. Haydary, J. "Chemical process design and simulation: Aspen Plus and Aspen Hysys applications" John Wiley & Sons. 2018
5. Ghasem, N. "Modeling and Simulation of Chemical Process Systems" (1st ed.). CRC Press. 2018
6. Aris, R. and Varma, A. (Editors), "The Mathematical Understanding of Chemical Engineering Systems: Selected Papers of N. R. Amundson," Pergamon Press 1980.

LECTURE PLAN

Lecture No.	Topics to be covered
1.	Definition of sustainability in process engineering;
2.	Introduction to modelling and simulation in the context of sustainability
3.	Industrial usage of process modelling and simulation;
4.	Models and their classification
5.	Model building
6.	Modelling difficulties
7.	Degree-of-freedom analysis, Selection of design variables
8.	Macroscopic mass, energy and momentum balances;
9.	Incorporation of fluid thermodynamics, chemical equilibrium, reaction kinetics and feed/ product property estimation in mathematical models.
10.	Review of numerical techniques for solving steady state and unsteady state models.
11.	Process modeling and tools for simulation; Overview of commercial tools (Aspen Plus, HYSYS, CHEMCAD, DWSIM, etc.)
12.	Planning of calculation in a plant simulation.
13.	Models of Heat Transfer Equipment
14.	Development of detailed mathematical models of evaporators
15.	Use of Newton Raphson method for solving evaporator problems.
16.	Models of Separation Processes
17.	Separation of multi components mixtures by use of a single equilibrium stage, flash calculation under isothermal and adiabatic conditions.
18.	Tridigonal formulation of component material balances and equilibrium relationships for distillation, absorption and extraction of multi components.

19.	Unsteady state lumped systems and dynamic simulation
20.	Time-dependent process behaviour, Introduction to Aspen Dynamics, Simulink
21.	Computer algorithms for numerical solution of steady state and unsteady state models.
22.	Process modeling with dispersion; axial mixing; diffusion, etc.
23.	Models of absorbers, strippers and extractors.
24.	Simulations approach, Concept of steady-state, Mass and energy balances under steady-state
25.	Simulation workflow in steady-state tools.
26.	Use of process simulators for flow sheet simulation.
27.	Building process flowsheets
28.	Sequential vs equation-oriented simulation
29.	Convergence strategies, Troubleshooting simulation models
30.	Data input and output interpretation, Sensitivity analysis, Convergence strategies
31.	Introduction to application of artificial intelligence-based modeling methods
32.	Use of Artificial Neural Networks, Fuzzy logic, etc. in process modeling
33.	Case study on simulations of sustainable processes
34.	Case study on simulations of Divided-wall columns (DWC)
35.	Case study on simulations of ammonia synthesis
36.	Case study on simulations of Bio-based processes
37.	Case study on simulations of Bio-based processes (continue)
38.	Case study on simulations of CO_2 capture and utilization (CCU)
39.	Case study on simulations of CO_2 capture and utilization (CCU) (continue)
40.	Case study on simulations of Waste-to-energy systems

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT805	Computational Techniques for Sustainable Processes	4	3	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

To learn various computational techniques for analyzing and solving chemical engineering problems.

COURSE OUTCOMES

CO1	Understanding of fundamental mathematics and to solve problems of algebraic and differential equations, partial differential equations
CO2	Ability to convert problem solving strategies to procedural algorithms and to write program structures
CO3	Ability to solve engineering problems using computational techniques
CO4	Ability to assess reasonableness of solutions, and select appropriate levels of solution sophistication

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following four components;

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Linear and Non-Linear Algebraic Equations: Introduction, Gauss-Elimination, Gauss-Siedel and LU Decomposition methods, Thomas' algorithm, Single variable and multivariable successive substitution method, single variable and multivariable Newton-Raphson technique, Polynomial root finding methods.

(No. of lectures- 8)

Unit II- Eigen Values and Eigen Vectors of Matrices: Introduction, Fadeev-Leverrier's method, Power method.

(No. of lectures- 4)

Unit III- Function Approximation: Least squares curve fit, Newton's interpolation formulae, Lagrangian interpolation, Pade approximation, Cubic spline approximation. Integration formulae: Trapezoidal rule, Simpson's rule.

(No. of lectures- 6)

Unit IV- Ordinary Differential Equations: Initial Value Problems: Explicit Adams-Bashforth technique, Implicit Adams-Moulton technique, Predictor-corrector technique, Runge-Kutta methods, Stability of algorithms. Boundary Value Problems: Finite difference technique, Orthogonal Collocation (OC), Shooting Techniques.

(No. of lectures- 8)

Unit V- Partial Differential Equations: Classification of PDE, Finite difference technique (Method of lines), Orthogonal collocation.

(No. of lectures- 8)

Unit VI- Case studies: Use of Spreadsheets and MATLAB in Chemical Engineering and Case Studies pertaining to sustainable chemical processes

(No. of lectures- 6)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Gupta, S. K. Numerical Methods for Engineers, New Age International Ltd., New Delhi 2019
2. Finlayson, B. A. Introduction to Chemical Engineering Computing, Wiley- Interscience 2006.
3. Curtis, G. and Patrick, W.O., Applied Numerical Analysis, Pearson Education Inc. 2004
4. Constantinides, A. and Mostoufi, N. Numerical Methods for Chemical Engineers with MATLAB Applications, Prentice Hall 1999
5. Hanna, O.T. and Sandall, O.C. Computational Methods in Chemical Engineering, Prentice-Hall 1995

LECTURE PLAN

Lecture No.	Topics to be covered
1.	Linear and Non-Linear Algebraic Equations
2.	Gauss-Elimination
3.	Gauss-Siedel
4.	LU Decomposition methods
5.	Thomas' algorithm
6.	Single variable and multivariable successive substitution method
7.	Single variable and multivariable Newton-Raphson technique
8.	Polynomial root finding methods
9.	Eigen Values of Matrices
10.	Eigen Vectors of Matrices
11.	Fadeev-Leverrier's method
12.	Power method
13.	Least squares curve fit
14.	Newton's interpolation formulae
15.	Lagrangian interpolation,
16.	Pade approximation
17.	Cubic spline approximation
18.	Integration formulae: Trapezoidal rule, Simpson's rule

19.	Ordinary Differential Equations: Initial Value Problems
20.	Explicit Adams-Bashforth technique
21.	Implicit Adams-Moulton technique
22.	Predictor-corrector technique
23.	Runge-Kutta methods
24.	Stability of algorithms
25.	Boundary Value Problems: Finite difference technique,
26.	Orthogonal Collocation (OC), Shooting Techniques.
27.	Partial Differential Equations
28.	Classification of PDE
29.	Finite difference technique-1
30.	Finite difference technique-2
31.	Finite difference technique-3
32.	Method of lines
33.	Graphical representation of PDE
34.	Orthogonal collocation
35.	Use of Spreadsheets
36.	MATLAB in Chemical Engineering-1
37.	MATLAB in Chemical Engineering-2
38.	MATLAB in Chemical Engineering-3
39.	Case Studies
40.	Case Studies cont.

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT806	Process Integration and Intensification	4	3	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

To understand the energy and mass targets in design of processes, and to focus on the working and application of intensified equipment and techniques that potentially lead to compact, safe, energy-efficient and environment-friendly sustainable processes.

COURSE OUTCOMES

CO1	Learn the concept of pinch analysis, heat and mass integration.
CO2	Analyze and design heat exchanger networks. Understand the fundamentals of process intensification.
CO3	Use of process intensification for separation and multifunctional reactors.

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following four components;

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Introduction: Process integration, Role of thermodynamics in process design, Concept of pinch technology and its application. Heat exchanger networks: Heat exchanger networks analysis, Grand Composite curve (GCC), Maximum energy recovery (MER), Loop Breaking & Path Relaxation, Targeting of energy, area, number of units and cost, Computer aided tools (Hint, Aspen energy analyzer).

(No. of lectures- 8)

Unit II- Network Integration: Super targeting, Trading off energy against capital, Network for multiple utilities and multiple pinches, Heat integration of distillation column.

(No. of lectures- 8)

Unit III- Mass Integration: Concept of mass exchanger networks, Concentration interval method, Composite curve method, Minimum mass separating agent and number of mass exchangers.

(No. of lectures- 8)

Unit IV Concept of Process Intensification (PI): Principles, Need of process Intensification, Micro-reactors, Micro-channel heat exchangers, Monolithic catalyst and reactors, Concept of HIGEE and rotating contactors, Hydrodynamic cavitation.

(No. of lectures- 8)

Unit V- Multifunctional Reactors and Hybrid Separations: Concept and principles of Distillation, Extraction, Absorption, Adsorption, Integration of reaction, heat and mass transfer, fermentation-pervaporation, reactive distillation, membrane distillation, Membrane reactors etc.

(No. of lectures- 8)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Linnhoff, D.W., User Guide on Process Integration for the Efficient Use of Energy, Institution of Chemical Engineers, 1994.
2. Smith, R., Chemical Process Design and Integration, John Wiley & Sons 2005
3. Stankiewicz, A., and Moulijn. J. A., Re-engineering the Chemical Processing Plant: Process Intensification, Marcel Dekker, Inc., New York 2004.
4. Shenoy, V. U., Heat Exchanger network synthesis, Gulf Publishing 1965.
5. Kumar, A., Chemical Process Synthesis and Engineering Design, Tata McGraw Hill 1977.
6. Mizrahi, J., Developing an Industrial Chemical Process: An Integrated Approach, CRC Press, 2002.

LECTURE PLAN

Lecture No.	Topics to be covered
1.	Definition and scope of Process Integration, Historical development and importance
2.	Differences between conventional process design and PII
3.	Role of thermodynamics in process design
4.	Process Integration fundamentals, Concept of pinch technology and its application, Grand Composite curve (GCC), Maximum energy recovery (MER),
5.	Heat exchanger network synthesis,
6.	Heat exchanger networks: Heat exchanger networks analysis
7.	Matchmaking and trade-offs in HEN, Loop Breaking and Path Relaxation,
8.	Targeting of energy, area, number of units and cost, Computer aided tools (Aspen energy analyzer).
9.	Types of utilities and role of utilities in energy systems, Importance of multiple utilities
10.	Network design for multiple utilities, modifying GCC to include multiple utility levels, Utility placement strategies
11.	Multiple Pinches – Concepts and Challenges, Causes of multiple pinches, Types of multiple pinches,
12.	Impact on energy targeting, Identification and characterization of multiple pinches
13.	Super targeting, Trading off energy against capital,
14.	Heat integration of distillation column.

15.	Utility Systems Integration, Steam and power system integration, Combined heat and power (CHP) systems
16.	Integration of both multiple utilities and multiple pinches, Trade-offs between utility costs and capital costs, Software tools for integration
17.	Concepts of mass exchange networks,
18.	Sources and sinks, Process pinch vs. mass pinch concept
19.	Composite Curves and Pinch Analysis, Construction of mass composite curves, identifying mass pinch points
20.	Graphical methods for network targeting,
21.	Minimum mass separating agent (MSA) and number of mass exchangers requirement
22.	Targeting Techniques-source-sink matching, minimum utility targeting
23.	Algebraic targeting procedures and Concentration interval method
24.	Mass exchanger units: absorber, stripper, membrane, etc.
25.	Process Intensification Fundamentals, Need of process Intensification
26.	Definition and drivers of PI, Types of process intensification: Spatial, temporal, functional, thermodynamic
27.	Technologies for process intensification
28.	Intensified Reactors- Microreactors, Spinning disc reactors (SDRs), Monolithic and structured reactors,
29.	Membrane reactors: concept and applications
30.	Reactive distillation and reactive extraction, Applications in petrochemical and pharmaceutical industries
31.	Heat and Mass Transfer Intensification**,**
32.	Compact heat exchangers, Heat pipes and thermosyphons, Intensification of absorption and stripping columns
33.	Separation Process Intensification**,** Dividing wall columns, Membrane-based separations,
34.	Concept and principles of Distillation, Extraction, Absorption, Adsorption
35.	Integration of reaction, heat and mass transfer
36.	Hybrid separation techniques
37.	Fermentation-pervaporation,
38.	Reactive distillation,
39.	Membrane distillation and reactors
40.	Industrial Applications and Case Studies, PI in chemical, pharmaceutical, food, and energy sectors.

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT807	Process Safety and Hazard Management	4	3	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

To deliver a broad level of risk identification and management in process plant integrity management.

COURSE OUTCOMES

CO1	Understand the fundamental principles underlying safety and risk management
CO2	Understand the toxicology, fire & explosion hazards
CO3	Establish expertise relevant to the practice of safety and risk management and undertake a Hazard and Operability Study (HAZOP)

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following four components;

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Introduction: Origin of process hazards, Laws Codes, Standards, Case Histories, Properties of Chemicals, Health hazards of industrial substances, Personal Protective equipment.

(No. of lectures- 8)

Unit II- Toxicology: Toxic materials and their properties, effect of dose and exposure time, relationship and predictive models for response, Threshold value and its definitions, material safety data sheets, industrial hygiene evaluation.

(No. of lectures- 5)

Unit III- Industrial Hygiene: Government Regulations, Industrial Hygiene identification, evaluating worker exposure to dust, noise, toxic vapor and volatile toxicants. Industrial hygiene control techniques.

(No. of lectures- 7)

Unit IV Fire and explosion: Fire and explosion hazards causes of fire and preventive methods. Flammability characteristics of chemical, fire and explosion hazard, rating of process plant. Propagation of fire and effect of environmental factors, ventilation, dispersion, purifying and sprinkling, safety and relief valves.

(No. of lectures- 7)

Unit V- Hazards Identification: Process Hazards checklists, Hazards surveys, hazards and operability studies, safety reviews.

(No. of lectures- 6)

Unit VI - Hazard Assessment: Failure distribution, failure data analysis, modeling for safety, safety training, emergency planning and disaster management, case studies

(No. of lectures- 7)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Crawl D.A. and Louvar J.A., "Chemical Process Safety Fundamentals with Applications," 4 th Ed.,Prentice Hall, 2020.
2. Lees, F. P., "Loss Prevention in Process Industries", Vol.1 and 2, 4th Ed., Butterworth, 2012.
3. Wentz, C.A., "Safety Health and Environmental Protection," McGraw Hill, 1998.

LECTURE PLAN

Lecture No.	Topics to be covered
1.	**Introduction:** Origin of process hazards
2.	Laws Codes
3.	Standards
4 & 5	Case Histories
6.	Properties of Chemicals
7.	Health hazards of industrial substances
8.	Personal Protective equipment
9.	**Toxicology:** Toxic materials and their properties, Effect of dose and exposure time
10.	Relationship and predictive models for response
11.	Threshold value and its definitions
12.	Material safety data sheets
13.	Industrial hygiene evaluation
14.	**Industrial Hygiene:** Government Regulations
15.	Industrial Hygiene identification
16 to 19	evaluating worker exposure to dust, noise, toxic vapor and volatile toxicants.
20	Industrial hygiene control techniques
21	**Fire and explosion:** Fire and explosion hazards causes of fire and preventive methods.
22	Flammability characteristics of chemical
23	Fire and explosion hazard
24	Rating of process plant
25	Propagation of fire and effect of environmental factors, ventilation,
26	Dispersion, purifying and sprinkling,

27	Safety and relief valves
28	Hazards Identification: Process Hazards checklists
29 & 30	Hazards surveys
31 & 32	Hazards and operability studies
33	Safety reviews
34	Hazard Assessment: Failure distribution
35	Failure data analysis
36	Safety training
37	Modeling for safety,
38	Emergency planning and disaster management
39 & 40	Case studies

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT808	Biochemical Engineering	4	3	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

To impart the knowledge of enzyme kinetics, cell growth and application of the same for biochemical processes.

COURSE OUTCOMES

CO1	Understand the role of Chemical Engineers in bioprocess industries.
CO2	Understand concept of enzyme and its working, cell growth kinetics and inhibition kinetics.
CO3	Design of downstream equipment for product separation.
CO4	Design of bioreactor/ fermenter

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following four components;

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Introduction: Interaction of chemical engineering principles with biological sciences. Life processes, unit of living system, microbiology, reaction in living systems, Chemicals of Life.

(No. of lectures- 9)

Unit II- Biocatalysts: Enzyme Kinetics, Mechanism and Inhibition models, Immobilized Enzymes-Methods, Kinetics and diffusion limitations.

(No. of lectures- 8)

Unit III- Sterilization: Sterilization of media and air, sterilization equipment, batch and continuous sterilize design.

(No. of lectures- 5)

Unit IV- Cell Growth - kinetic models of microbial growth and product formation, Stoichiometry of cell growth. Fermenter types; Modeling of batch and continuous fermenter. Bioreactor design, mixing phenomena in bioreactors.

Fermentation: Fermentation mechanisms and kinetics.

(No. of lectures- 9)

Unit V- Post Fermentation Techniques: Biochemical product recovery and separation. Membrane separation process: reverse osmosis, dialysis, ultrafiltration; Chromatographic methods: adsorption chromatography, gel filtration, affinity chromatography etc. Electro-kinetic separation: electro-dialysis, electrophoresis.

(No. of lectures- 9)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Shuler, M.L. and Kargi, "Bioprocess Engineering Basic Concepts," 2nd Ed., Prentice Hall of India, New Delhi, 2001.
2. Bailey &Ollis, Biochemical Engg. Fundamentals, 2nd Ed. McGraw Hill, 2007.
3. Dubey R.C., "A Textbook of Biotechnology", 5th Ed. S. Chand and Co., New Delhi, 2014.
4. Schugerl, K. and Bellgardt, K. V., Bioreaction Engineering: Modeling and Control, Springer Verlag, Heidelberg, 2011.
5. Doran P., Bioprocess Engineering Principles, 2nd Ed. Academic Press, NewYork, 2012.
6. Blanch H. W. and Clark D. S., Biochemical Engineering, 2nd Ed. Dekker, NewYork, 1997.

LECTURE PLAN

Lecture No.	Topics to be covered
1 & 2	Interaction of chemical engineering principles with biological sciences
3.	Interaction of chemical engineering principles with biological sciences, cont..
4.	Unit of living system
5.	Unit of living system, cont..
6.	Microbiology
7.	Microbiology, cont..
8.	Reaction in living systems,
9.	Chemicals of Life
10.	Enzyme Kinetics
11.	Enzyme Kinetics, cont..
12.	Mechanism and Inhibition models
13.	Mechanism and Inhibition models, cont..
14.	Immobilized Enzymes-Methods
15.	Immobilized Enzymes-Methods, cont..
16.	Kinetics and diffusion limitations
17.	Kinetics and diffusion limitations, cont..
18.	Sterilization of media and air
19.	Sterilization equipment
20.	Batch and continuous sterilize design
21.	Batch and continuous sterilize design, cont..
22.	Batch and continuous sterilize design, cont..
23.	Kinetic models of microbial growth and product formation
24.	Stoichiometry of cell growth
25.	Fermenter types: Modeling of batch and continuous fermenter
26.	Fermenter types: Modeling of batch and continuous fermenter, cont..
27.	Bioreactor design, mixing phenomena in bioreactors
28.	Bioreactor design, mixing phenomena in bioreactors, cont..
29 to 31	Fermentation: Fermentation mechanisms and kinetics

32.	Biochemical product recovery and separation
33.	Reverse osmosis
34.	Dialysis
35.	Ultrafiltration
36.	Chromatographic methods: adsorption chromatography
37.	Gel filtration, affinity chromatography
38 to 40	Electro-kinetic separation: electro-dialysis, electrophoresis

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT809	Statistical Methods	**4**	**3**	**0**	**2**	**0**

PREREQUISITE: NIL

COURSE OBJECTIVE

To provide the fundamentals of experimental designs, analysis tools and techniques, interpretation and applications.

COURSE OUTCOMES

CO1	The fundamentals of experiments and basic statistics, including ANOVA and regression
CO2	Application of statistical models in analysing experimental data
CO3	Experimental design and RSM to optimize the response of interest from an experiment
CO4	Use of statistical software

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following four components;

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Introduction to design and analysis of experiments: Basic concepts and applications, Basic statistics, Analysis of Variance (ANOVA), Regression techniques, Hypothesis testing in multiple regression, Confidence intervals in multiple regression

(No. of lectures- 10)

Unit II- Experimental designs: Randomized complete block design (RCBD), Variants of RCBD such as Latin Square, central composite design, BBD etc.

(No. of lectures- 8)

Unit III- Experimental designs: Full factorial experiments, 2k factorial experiments, Fractional factorial experiments, 2k-p factorial experiments

(No. of lectures- 8)

Unit IV- Response surface methodology: Response surface methodology (RSM), the method of Steepest Ascent, Experimental designs for fitting Response Surfaces, Designs for fitting the First-Order Model, Designs for fitting the Second-Order Model, and Evolutionary operation.

(No. of lectures- 8)

Unit V- Introduction to statistical softwares

(No. of lectures- 6)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Montgomery, D. C. Design and Analysis of Experiments, Wiley 2019
2. Krishnaiah, K.; Shahabudeen, P. Applied Design of Experiments and Taguchi Methods, Prentice Hall of India 2012
3. Panneerselvam, R. Design and Analysis of Experiments, Prentice Hall of India 2012
4. Holman, J.P. Experimental Methods for Engineers", McGrawHill, Singapore 2011
5. Box, G. E. P.; Stuart Hunter, J.; Hunter,W. G. Statistics for Experimenters: Design, Innovation, and Discovery, Wiley 2005

LECTURE PLAN

Lecture No.	Topics to be covered
1.	Introduction to design and analysis of experiments
2.	Basic concepts and applications
3.	Basic statistics
4.	Several statistical formulas
5.	Analysis of Variance (ANOVA)
6.	Regression techniques
7.	Linear and non-linear model fitting
8.	Hypothesis testing in multiple regression
9.	Confidence intervals in multiple regression
10.	Advanced statistical techniques
11.	Experimental designs-1
12.	Experimental designs for different processes
13.	Randomized complete block design (RCBD)
14.	Variants of RCBD
15.	Latin Square methods
16.	Central composite design
17.	BBD
18.	Other design models
19.	Experimental designs
20.	Full factorial experiments
21.	2k factorial experiments
22.	Fractional factorial experiments
23.	2k-p factorial experiments
24.	Statistical formulas related to factorial design
25.	Comparison with different models
26.	Selection of best models
27.	Response surface methodology (RSM)
28.	The method of Steepest Ascent
29.	Experimental designs for fitting Response Surfaces
30.	Designs for fitting the First-Order Model
31.	Designs for fitting the Second-Order Model

32.	Comparison with different models
33.	Selection of best models
34.	Evolutionary operation
35.	Introduction to statistical softwares
36.	Statistical softwares-1
37.	Statistical softwares-2
38.	Statistical softwares-3
39.	Statistical softwares-4
40.	Comparison and selection of best models with different models

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practica l	Studio
25CHT810	AI and ML in Process Engineering	**4**	**3**	**0**	**2**	**0**

PREREQUISITE: NIL

COURSE OBJECTIVE

To provide comprehensive knowledge of various AI and ML techniques and their applications in chemical engineering problems. To implement machine learning models using programming languages and tools such as Python, TensorFlow, and Scikit-learn.

COURSE OUTCOMES

CO1	Understand the fundamentals of AI and ML
CO2	Integrate chemical engineering domain knowledge into AI/ML solutions whereby making students equipped for in-demand careers.
CO3	Design and implement ML models such as regression, regularization methods, decision tree, Naïve-Bayes.
CO4	Design and implement ML models such as support vector machine, neural networks, etc.
CO5	Develop problem solving skills in Python, Tensorflow, Keras, sci-kit learn

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following four components;

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Introduction to Artificial Intelligence (AI) and Machine Learning (ML); Types of learning problems: Supervised, Unsupervised, Semisupervised, Overview of optimization techniques: An introduction to Python programming language, list, tuples, set, dictionary. Libraries such as Pandas, NumPy, matplotlib, sklearn.

(No. of lectures- 8)

Unit II- Optimization technique such as Gradient Descent method: Simple linear regression, multiple linear regression, Regularization methods (Ridge, Lasso, ElasticNet regression).

(No. of lectures- 8)Unit III- Logistic regression, K-Nearest Neighbours algorithm, Decision Trees, Random Forest, Naïve Bayes classifier.

(No. of lectures- 8)

Unit III- Logistic regression, K-Nearest Neighbours algorithm, Decision Trees, Random Forest,Naïve Bayes Classifier. **(No. of lectures- 8)**

Unit IV- Support Vector Machine, Neural Networks: Single layer neural network, Multilayer neural network, Use of Tensorflow and Keras libraries. **(No. of lectures- 8)**

Unit V- Data Preprocessing, Principal Component Analysis, KMeans cluster analysis, ARIMA model.

(No. of lectures- 8)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Géron, A. (2023), Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow, 3rd edition, O'Reilly Media, Inc. 2023
2. Raschka, S., &Mirjalili, V., Python machine learning: Machine learning and deep learning with Python, scikit-learn, and TensorFlow 2. Packt publishing ltd. 2019
3. Pradhan, M., Kumar, U.D., (2019), Machine Learning using Python, Wiley India Pvt. Ltd. 2019
4. Grus, J. (2019), Data Science from Scratch, 2nd edition, O'Reilly Media, Inc. 2019
5. Müller, A. C., Gudio, Introduction to Machine Learning with Python, O'Reilly Media, Inc., 2018

LECTURE PLAN

Lecture No.	Topics to be covered
1.	Introduction to Artificial Intelligence (AI) and Machine Learning (ML)
2.	Introduction to Machine Learning (ML)
3.	Types of learning problems: Supervised, Unsupervised, Semisupervised.
4.	Overview of optimization techniques
5.	An introduction to Python programming language
6.	List, tuples, set and dictionary
7.	Libraries such as Pandas and NumPy
8.	Libraries such as matplotlib and sklearn.
9.	Optimization techniques
10.	Gradient Descent method
11.	Simple linear regression
12.	Multiple linear regression
13.	Regularization methods
14.	Ridge methods
15.	Lasso methods
16.	ElasticNet regression methods
17.	Logistic regression-1
18.	Logistic regression-2
19.	K-Nearest Neighbours algorithm
20.	Decision Trees
21.	Random Forest
22.	Naïve Bayes classifier
23.	Other models
24.	Sophisticated models

25.	Support Vector Machine
26.	Neural Networks
27.	Single layer neural network
28.	Multilayer neural network
29.	Use of Tensorflow-1
30.	Use of Tensorflow-2
31.	Use of Keras libraries-1
32.	Use of Keras libraries-2
33.	Data Preprocessing-1
34.	Data Preprocessing-2
35.	Principal Component Analysis-1
36.	Principal Component Analysis-2
37.	KMeans cluster analysis-1
38.	KMeans cluster analysis-2
39.	ARIMA model
40.	Others models for AI

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT811	Advanced Thermodynamics	4	3	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

To provide concepts of solution thermodynamics for multicomponent systems.

COURSE OUTCOMES

CO1	Able to understand intermolecular forces and relate to macroscopic thermodynamic properties.
CO2	Differentiate between ideal and non-ideal thermodynamic behavior in both pure substances and mixtures.
CO3	Explain phase equilibria for multicomponent systems and understand the thermodynamics properties of mixtures and solutions.
CO4	Evaluate and apply different methods/assumptions for performing phase equilibrium calculations and explain multi-reaction equilibria

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following four components;

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Review of Classical Thermodynamics: Properties of pure fluids, Thermo Properties from Volumetric Data, Equations of State, Generalized correlations.

(No. of lectures- 6)

Unit II- Intermolecular Interactions and Corresponding State Theory: Origin of interactions (Permanent, induced and instantaneous dipoles), Intermolecular forces and potential energy functions, Corresponding states theory.

(No. of lectures- 10)

Unit III- Thermodynamic Properties of Mixtures: Mixtures, partial molar properties, Chemical potential, Gibbs Duhems equations, Property changes on mixing, Fugacity in gas mixtures-Virial and Cubic EOS, corresponding states, fugacities in liquid mixures, fugacities in liquid mixures (electrolyte solution) Excess Functions in Liquid Mixtures, Models for Excess Gibbs energy. **(No. of lectures- 12)**

Unit iv- Phase Equilibria: Multiphase Multicomponent phase equilibrium, VLE/SLE/LLE/VLLE, Solubility of gases in liquids, solubility of solids in liquids.
(No. of lectures- 6)

Unit V- Chemical Equilibrium and molecular simulation: Combined phase and Reaction equilibrium, Introduction to Molecular Simulation.
(No. of lectures- 6)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. J.M. Prausnitz, R.M. Lichtenthaler and E.G. Azevedo, Molecular Thermodynamics of Fluid Phase Equilibria,3rd edition, Prentice Hall Inc., New Jersey, 1999.
2. J.M. Smith. H.C. Van Ness and M.M.Abott, Introduction to Chemical Engineering Thermodynamics, 8th edition, McGraw Hill International edition, 2018.
3. S. I. Sandler, Chemical, Biochemical, and Engineering Thermodynamics, 5th Edition, John Wiley & Sons, Inc.,2017. ISBN: 978-1-119-32128-6, 2017.
4. B. E. Poling, J. M., Prausnitz, J. P. O'Connell, The Properties of Gases and Liquids, 5th edition, McGraw Hill, 2001.
5. J.W. Tester and M. Modell, Thermodynamics and Its Applications, 3rd ed.,Prentice Hall, NJ, 1997.

LECTURE PLAN

Lecture No.	Topics to be covered
1.	**Review of Classical Thermodynamics:** Properties of pure fluids
2.	Thermo Properties from Volumetric Data
3 & 4	Equations of State
5 & 6	Generalized correlations
7.	**Intermolecular Interactions and Corresponding State Theory:** Origin of interactions
8 to 10	Permanent induced and instantaneous dipoles
11 & 12	Intermolecular forces
13 & 14	potential energy functions
15 & 16	Corresponding states theory
17 & 18	**Thermodynamic Properties of Mixtures:** Mixtures, partial molar properties
19	Chemical potential
20	Gibbs Duhems equations,
21 & 22	Property changes on mixing, Fugacity in gas mixtures-Virial and Cubic EOS
23 to 25	corresponding states, fugacities in liquid mixures, fugacities in liquid mixures (electrolyte solution)
26	Excess Functions in Liquid Mixtures
27 & 28	Models for Excess Gibbs energy
29	**Phase Equilibria:** Multiphase Multicomponent phase equilibrium
30 to 32	VLE/SLE/LLE/VLLE
33 & 34	Solubility of gases in liquids
35 & 36	solubility of solids in liquids

37 & 38	**Chemical Equilibrium and molecular simulation:** Combined phase and Reaction equilibrium
39 & 40	Introduction to Molecular Simulation

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT812	Clean Technologies for Pollution Control	4	3	0	2	0

PREREQUISITE: NIL

COURSE OBJECTIVE

To provide concepts of water and air pollution, related legislation and technologies for pollution abatement.

COURSE OUTCOMES

CO1	Quantify and analyze the pollution load
CO2	Analyze/design of suitable treatment operation for wastewater
CO3	Model the atmospheric dispersion of air pollutants and design of air pollution control devices.
CO4	Gained knowledge of the Environmental legislation and standards

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following four components;

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I- Introduction: Sources of water, air and land pollution and socioeconomic impacts, Concept of EIA, Legislation and standards.

(No. of lectures- 6)

Unit II- Water Pollution: Surface water quality parameters, Dissolved Oxygen balance model and Oxygen sag curve, Wastewater Treatment Plant design: Physical unit operations, disinfection, adsorption, Aerobic and anaerobic biological treatment processes, Activated sludge reactor design, anaerobic reactors design, Trickling filter, Bio-tower, UASB.

(No. of lectures- 14)

Unit III- Advanced wastewater treatment technology: electro-chemical treatment methods, advanced oxidation processes, ion exchange, membrane technology etc.

(No. of lectures- 8)

Unit IV Air Pollution: Air pollution meteorology, plume and its behavior, Air quality modeling for point, line and area sources, Dispersion modeling for short and tall stacks for short and long distances, Monitoring of air pollutants. Air Pollution abatement technologies and systems for particulate matter and gaseous constituents.

(No. of lectures-12)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. Peavy, H. S., Rowe, D. R., Tchobanoglous, G., Environmental Engineering, McGraw Hill, 1995.
2. Sincero, P., and Sincero, G.A., Environmental Engineering: A Design Approach, Prentice Hall, 1996.
3. Masters, G.M., Introduction to Environmental Engineering and Science, Prentice Hall, 2006
4. Metcalf & Eddy, Inc., Wastewater Engineering: Treatment and Reuse, 4th ed., Tata McGraw Hill, 2003.
5. 5.Arceivala S.J. and Asolekar S.R., Wastewater Treatment for Pollution Control and Reuse, 3rd Ed., Tata McGraw Hill, 2007.

LECTURE PLAN

Lecture No.	Topics to be covered
1.	**Introduction:** Sources of water, air and land pollution and
2.	Socioeconomic impacts
3.	Concept of EIA
4.	Legislation
5.	Legislation Cont.
6.	Standards
7.	Water Pollution: Surface water quality parameters
8.	water quality parameters Cont.
9.	water quality parameters Cont.
10.	Dissolved Oxygen balance model
11.	Oxygen sag curve
12.	Wastewater Treatment Plant design
13.	Physical unit operations
14.	Disinfection
15.	Concept of Aerobic and anaerobic biological treatment processes
16.	Activated sludge reactor design
17.	Trickling filter
18.	Bio-tower
19.	Anaerobic reactors design
20.	UASB
21.	Advanced wastewater treatment technology: Advanced oxidation processes (AOP)
22.	Concept of AOP and Mechanism
23.	Classification of AOP
24.	Electro-chemical treatment methods- Electro-Oxidation
25.	Electro-Fenton

26.	Ion exchange
27.	Membrane technology
28.	Membrane technology cont.
29.	Air Pollution: Source and classification.
30.	Air pollution meteorology
31.	Plume and its behavior
32.	Air quality modeling for point source
33.	Air quality modeling for line and area sources
34.	Dispersion modeling for short and tall stacks for short distances
35.	Dispersion modeling for short and tall stacks for long distances
36.	Monitoring of air pollutants
37 & 38	Air Pollution abatement technologies and systems for particulate matter
39 & 40	Air Pollution abatement technologies and systems for particulate matter cont.

DETAILS OF THE COURSE

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
25CHT813	Catalysis Science and Technology	**4**	**3**	**0**	**2**	**0**

PREREQUISITE: NIL

COURSE OBJECTIVE

To provide a fundamental understanding of homogeneous and heterogeneous catalysis

COURSE OUTCOMES

CO1	Principles of catalysis and its role in chemical processes, design and evaluate catalysts for specific reactions
CO2	Analyze and interpret data from catalytic experiments.
CO3	Understand the possible catalytic reaction pathway model and Apply knowledge of catalysis to solve real-world engineering problems

COURSE ASSESSMENT

The Course Assessment (culminating to the final grade), will be made up of the following four components;

S. No.	Component	Weightage
a)	Weekly Submissions/assignments, Quiz(s), and Attendance	20%
b)	Mid-term examination	20%
c)	Practical Examination	20%
d)	End Semester Examination	40%

COURSE CONTENTS

Unit I-Fundamentals of Catalysis: Homogeneous and Heterogeneous Catalysis, Preparation methods, Steps in catalytic reaction, Analysis of external transport processes in heterogeneous reactions in fixed bed, fluidized bed and slurry reactors. Intrapellet mass transfer, heat transfer, mass transfer with chemical reaction and simultaneous mass and heat transfer with chemical reaction.

(No. of lectures- 12)

Unit II- Catalyst Selectivity: Effect of intra pellet diffusion on selectivities in complex reactions, effect of external mass transfer on selectivities.

(No. of lectures- 6)

Unit III- Catalyst Deactivation: Modes of deactivation – poisoning, fouling and sintering. Determination of deactivation routes, combined effect of deactivation and diffusion on reaction rates, effect of deactivation on selectivity.

(No. of lectures- 6)

Unit IV- Reactor Design: Design calculation for ideal catalytic reactor operating at isothermal, adiabatic and non-adiabatic conditions. Deviations from ideal reactor performance. Design of industrial fixed-bed, fluidized bed and slurry reactors. Thermal stability of packed bed and fluidized bed reactors.

(No. of lectures- 8)

Unit V- Industrial Applications: Petrochemicals (cracking, reforming, hydrotreating), Biorefining (biofuel, chemicals synthesis processes), and Environmental Catalysis (CO_2 reduction, NO_x removal, etc.)

(No. of lectures- 8)

TEXT BOOKS/ REFERENCE BOOKS (Title, Authors, Publisher, & Year):-

1. H. S. Fogler, Elements of Chemical reaction engineering 2022
2. Smith, J. M., "Chemical Engineering Kinetics," 3rd ed., McGraw-Hill 2013
3. Tarhan, M. O., "Catalytic Reactor Design," McGraw-Hill, NY 1983
4. Carberry, J. J.," Chemical and Catalytic Reaction Engineering," McGraw-Hill (Dover Edition) 2001
5. Thomas, J. M. and Thomas, W. J., "Introduction to the Principles of Heterogeneous Catalysis," Academic Press 1967

LECTURE PLAN

Lecture No.	Topics to be covered
1.	Homogeneous and Heterogeneous Catalysis
2.	Preparation methods
3.	Steps in catalytic reaction,
4.	Analysis of external transport processes in heterogeneous reactions
5.	Fixed bed reactor
6.	Fluidized bed and slurry reactors
7.	Intrapellet mass transfer
8.	Heat transfer with chemical reaction
9.	Mass transfer with chemical reaction-1
10.	Mass transfer with chemical reaction-2
11.	Simultaneous mass and heat transfer with chemical reaction-1
12.	Simultaneous mass and heat transfer with chemical reaction-2
13.	Catalyst selectivity
14.	Effect of intra pellet diffusion
15.	Parameters related to inter pellet diffusion
16.	Diffusion on selectivities of complex reactions
17.	Effect of external mass transfer on selectivities.
18.	Parameters related to external mass transfer
19.	Catalyst Deactivation
20.	Modes of deactivation – poisoning, fouling and sintering.
21.	Determination of deactivation routes
22.	Combined effect of deactivation and diffusion on reaction rates-1

23.	Combined effect of deactivation and diffusion on reaction rates-2
24.	effect of deactivation on selectivity
25.	Reactor Design
26.	Design calculation for ideal catalytic reactor operating at isothermal
27.	Design calculation for ideal catalytic reactor operating at adiabatic and non-adiabatic conditions
28.	Deviations from ideal reactor performance
29.	Design of industrial fixed-bed
30.	Fluidized bed and slurry reactors
31.	Thermal stability of packed bed reactors
32.	Thermal stability of fluidized bed reactors
33.	Petrochemicals processes: cracking
34.	Petrochemicals processes: hydrotreating
35.	Petrochemicals processes: reforming
36.	Biorefining
37.	Biofuel (chemicals synthesis process)
38.	Environmental Catalysis
39.	CO_2 reduction
40.	NO_x removal