V Semester:

S.No.	Course Code	Course Title	Category	Type	Credit	L	T	P
1.	22CHT301	AI & ML in Chemical Engineering	PC	Theory	4	3	1	0
2.	22CHT302	Chemical Reaction Engineering-II	PC	Theory	4	3	1	0
3.	22CHT303	Mass Transfer-II	PC	Theory	4	3	1	0
4.	22CHT304	Process Dynamics and Control	PC	Theory	4	3	1	0
5.	22CHT305	Process Safety and Hazards Management	PC	Theory	4	3	1	0
6.	22CHP306	Mass Transfer Lab	PC	Lab	1	0	0	2
7.	22CHP307	Process Instrumentation and Control Lab	PC	Lab	1	0	0	2
Total					**22**	**15**	**5**	**4**

SEMESTER – V

1. **Subject Code: 22CHT301 Course Title: AI & ML in Chemical Engineering**
2. Contact Hours: L: 3 T: 1 P: 0
3. Credits: 4 Semester: V
4. Pre-requisite: Nil.
5. Course Objective:To provide comprehensive knowledge of various AI and ML tools and their applications in solving Chemical Engineering Problems.
6. Course Outcomes: Upon completion of this course, the students will be able to:
   i. Understand the fundamentals of AI and ML, tools used in Al & ML.
   ii. Integrate chemical engineering domain knowledge into AI/ML solutions whereby making students equipped for in-demand careers.
7. Details of Course:

Unit No.	Contents	Contact Hours
1.	Introduction to Artificial Intelligence (AI) and Machine Learning (ML); Types of learning problems: Supervised, Unsupervised, Semi-supervised; Overview of optimization techniques.	10
2.	Introduction to software tools used in AI & ML; Solving problems in Chemical Engineering (like decision support system, process control, modeling and simulation) applying rule-based AI & ML tools and lifecycle: (i) Data preprocessing: Data visualization, Outlier detection, & Smoothing techniques, Data scaling (Need for Scaling – Scale invariance, Standardization, Normalization), Dimensionality reduction, Feature extraction, selection (ii) Model Evaluation & identification: Performance metrics, analysis, Model selection, Hybrid cross-Validation methods (iii) Model development: (a) Classification – (Logistic regression, Naïve Bayes classifier, K-nearest neighbors, Support vector machines, Decision trees, Random forests, Boosting), (b) Regression - (Linear regression – simple, multiple, Kernel, Regression analysis, Box-Jenkins models (ARMA, ARIMA), Neural Network).	30

8. Books:

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Hastie, T., Tibshirani, R., Friedman, J.H., The Elements of Statistical Learning Data Mining, Inference, and Prediction, Second Edition, Springer.	2009
2	Abu-Mostafa, Y.S., Magdon-Ismail, M., Hsuan-Tein, L., Learning from Data. AMLBook.	2012
3	Bishop, C., Pattern Recognition and Machine Learning. Springer-Verlag.	2006
4	Gareth, J., Witten, D., Hastie. T., Tibshirani, R., An Introduction to Statistical Learning with Applications in R, Springer-Verlag.	2013
5	Müller, A. C., Gudio, S., Introduction to Machine Learning with Python, O'Reilly Media, Inc.	2016
6	Shalev-Shwartz, S. and Ben-David, S., Understanding Machine Learning: From Theory to Algorithms, Cambridge University Press.	2014

1. **Subject Code: 22CHT302 Course Title: Chemical Reaction Engineering-II**
2. Contact Hours: L:3 T:1 P:0
3. Credits: 4 Semester: V
4. Pre-requisite: Chemical Reaction Engineering-I
5. Course Objective: To understand the effect of non-ideal flow on reactor performance and to design reactors for heterogeneous reaction systems.
6. Course outcome: Upon completion of this course, the students will be able to:
   i. Diagnose non ideal flow in process vessels using concepts of RTD studies
   ii. Understand the fundamentals of Catalyst manufacture and its characterization
   iii. Understand the fundamentals of non-catalytic and catalytic heterogeneous reactions
   iv. Understand the fundamentals of gas-liquid reactions
   v. Design of heterogeneous reactors
7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Non-catalytic Gas-Solid Reactions:** Progressive conversion model, Shrinking core model; various controlling regimes, design of gas-solid reactors.	8
2.	**Catalyst synthesis & characterization**: Description, methods of catalyst preparation and manufacture; impregnation, sol-gel, catalyst characterization – BET surface area, pore volume, pore size distribution, catalyst promoters and inhibitors, catalyst poisoning, types of catalyst deactivation, kinetics of catalytic deactivation.	8
3.	**Catalyst Reaction Kinetic Models:** Physical and chemical adsorption; Determination of rate expressions using adsorption, surface reaction and desorption as rate-controlling steps. **Determination of Global Rate of Reaction**: Heterogeneous laboratory reactors; Determination of rate expressions from experimental data.	8
4.	**Effect of Intra-pellet Diffusion on Reaction Rates in Isothermal Pellets:** concept of effectiveness factor, Thiele modulus, experimental determination of effectiveness factor, falsified kinetics, Weisz-Prater criterion for internal diffusion, Mears criterion for external diffusion, Non-isothermal effectiveness factor; Prater number, maximum temperature rise in a pellet, multiple steady-states in heterogeneous reactors.	8
5.	**Gas-Liquid Reactions:** Effect of diffusion on rate of reaction, enhancement factor. **Introduction to Design of Heterogeneous Reactors:** One-dimensional model for fixed-bed reactors, parametric sensitivity; design of fluidized bed reactors.	8

8. **Books:**

(A) Text Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Levenspiel, O., "Chemical Reaction Engineering," 3rdEd., John Wiley.	2006
2	Fogler, H. S., "Elements of Chemical Reaction Engineering," 5thEd., Prentice-Hall of India, Delhi	2016
3	Smith, J. M., "Chemical Engineering Kinetics," 3rdEd., McGraw-Hill	1981

(B) Reference Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1	Carberry, J. J., "Catalytic Reaction Engineering," McGraw-Hill.	1976
2	Levenspiel, O., "The Chemical Reactor Omnibook," OSU Bookstores, Corvallis, Oregon.	1996

1. **Subject Code: 22CHT303** **Course Title: Mass Transfer II**
2. Contact Hours: L:3 T:1 P:0
3. Credits: 4 Semester: V
4. Pre-requisite: Mass Transfer-I
5. Course Objective:To learn the different separation techniques and analysis of mass transfer equipment
6. Course Outcomes: Upon completion of this course, the students will be able to:
   i. Develop the ability to develop analytical and graphical solution of separation by liquid-liquid Extraction and leaching.
   ii. Solve problem based on separation by adsorption and understood the design of adsorber for stage calculation,
   iii. Understand the operation of cooling tower, Dryer and mechanism of crystallization.

7. Details of Course:

Unit No.	Contents	Contact Hours
1.	**Liquid-Liquid & Solid/Liquid Extraction:** Ternary liquid equilibria, Triangular graphical representation concept of theoretical or ideal stage, Equipment used for single stage and multistage continuous operation; Analytical and graphical solution of single and multistage operation, Super critical fluid extraction. Leaching, Solid liquid equilibrium, Equipment used in solid – liquid extraction, Single and multistage cross current contact and counter current operations. Concept of an ideal stage, Overall stage efficiency, Determination of number of stages.	12
2.	**Adsorption:** Description of adsorption processes and their application, Types of adsorption, Nature of adsorbents, adsorption equilibria and adsorption hysteresis, Stage wise and continuous contact adsorption operations, Determination of number of stages.	10
3.	**Crystallization:** Equilibrium yield of crystallization, Heat and mass transfer rates in crystallization, Theories of crystallization, Factors governing nucleation and crystal growth rates, Controlled growth of crystal, Classification and design of crystallizers	6
4.	**Humidification and Dehumidification:**Vapour liquid equilibrium and enthalpy for a pure substance, vapour pressure temperature curve, Vapour gas mixtures, Definition and derivations of relationships related with humidity Fundamental concept of humidification, Dehumidification and water cooling,Wet bulb temperature, Adiabatic and non-adiabatic operations, Evaporative cooling,Classification and design of cooling towers.	6
5.	**Drying:** Solid-gas equilibria, Different modes of drying operations, Definitions of moisture contents, Types of batch and continuous dryers, Rate of batch drying, Time of drying, Mechanism of batch drying, Continuous drying, Design of continuous dryers.	6

8. **Books:**

(B) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Treybal, R "Mass Transfer Operations", 3rdEd. NewYork: McGraw-Hill.	2017
2	Sherwood T. K., Pigford R. L. and Wilke P. "Mass Transfer" McGraw-Hill.	1975
3	Geankoplis, CJ, "Transport Processes and Unit Operations", 3rdEd. Prentice Hall.	1993
4	B K Dutta, Principles of Mass Transfer and Separation Processes, PHI Learning.	2007

(C) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Foust A.S., Wenzel, L.A., Clump, C.W., Maus,L., Anderseny, L.B., "Principles of Unit Operations" 2nd Ed., John Wiley.	2008
2	King, C. J.," Separation Processes", 2nd Ed., McGraw-Hill, NY.	1980
3	Smith, B. D., "Design of Equilibrium Stage Processes", McGraw-Hill, NY.	1963
4	McCabe, W. L., Smith, J. C. and Harriot, P., "Unit Operations of Chemical Engineering", 7thEd., McGraw-Hill, NY.	2017
5	Coulson, J. M. and Richardson, J. F., " ChemicalEngineering",7thEd. Vol. I and II, Elsevier.	2017

1. **Subject Code: 22CHT304** **Course Title: Process Dynamics and Control**
2. Contact Hours: L:3 T:1 P:0
3. Credits: 4 Semester: V
4. Pre-requisite: Nil.
5. Course Objective: To learn the fundamentals of developing dynamic models of processes and control strategies for linear time-invariant systems
6. Course Outcomes: Upon completion of this course, the students will be able to:
   i. Develop transfer function models for linear dynamical processes
   ii. Characterize the dynamics and stability of processes based on mathematical analysis
   iii. Understand the principles of feedback controllers
   iv. Design PID controllers using different tuning rules
   v. Carry out a frequency-response analysis of control loop systems
7. Details of Course:

Unit No.	Contents	Contact Hours
1.	Introduction to process control and review of Laplace transforms. **Linear Open-Loop Systems** First-Order Systems: Transfer function, transient response (step response, impulse response, sinusoidal response),	8
2	**Examples of first-order systems, response of first-order systems in series**: non-interacting systems and interacting systems. Second-Order Systems: Transfer function, step response, impulse response, sinusoidal response, transportation lag.	8
3	**Linear Closed-Loop Systems** Control system: Components of a control system, block diagram, negative feedback and positive feedback, servo problem and regulator problem. Controller and final control element: Mechanism of control valve and controller, transfer functions of control valve and controllers (P, PI, PD, PID) Example of a chemical-reactor control systemClosed-Loop Transfer Functions: Overall transfer function for single-loop systems, overall transfer function for set-point change and load change, multi-loop control systems.	8
4	**Transient Response of Simple Control Systems:** P and PI control for set-point change and for load change. **Stability:** Concept of Stability; Stability criteria; Routh test for stability; Root Locus.	8
5	**Frequency Response:** Introduction to Frequency Response, Bode Diagrams for first- and second-order systems, Bode Stability Criteria, Ziegler-Nichols and Cohen-Coon Tuning Rules. Introduction to cascade, ratio and feed-forward controllers	8

8. **Books:**

(A) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Coughanowr, D. R., LeBlanc, S.E., "Process Systems Analysis and Control", 3rdEd., McGraw Hill.	2017
2	Stephanopoulos, G., "Chemical Process Control", PHI, New Delhi.	2015

(B) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Luyben, W. L., "Process Modeling, Simulation and Control for Chemical Engineers," 2ndEd., McGraw Hill.	2013
2	Bequette, B.W., "Process Control - Modeling, Design and Simulation," Pretice Hall.	2003
3	Seborg, D.E., Edgar, T.F., Mellichamp, D.A., Doyle III, F.A., "Process Dynamics and Control," 4th Ed., Wiley.	2016

1. **Subject Code: 22CHT305 Course Title: Process Safety and Hazards Management**
2. Contact Hours: L: 3 T: 1 P: 0
3. Credits: 4 Semester: V
4. Pre-requisite: Nil.
5. Course Objective: To deliver a broad level of risk identification and management in process plant integrity management. Student will be able to recognize and evaluate occupational safety and health hazards in the workplace
6. Course Outcomes: Upon completion of this course, the students will be able to:
   i. Understand the fundamental principles underlying safety and risk management
   ii. Understandthetoxicology, fire & explosion hazards
   iii. Establish expertise relevant to the practice of safety and risk management
   iv. Undertake a Hazard and Operability Study (HAZOP)
7. Details of Course:

Unit No.	**Contents**	**Contact Hours**
1.	Origin of process hazards, Laws Codes, Standards, Case Histories, Properties of Chemicals, Health hazards of industrial substances, Personal Protective equipment.	8
2.	**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.	5
3	**Industrial Hygiene:** Government Regulations, Industrial Hygiene identification, evaluating worker exposure to dust, noise, toxic vapor and volatile toxicants. Industrial hygiene control techniques.	7
4	**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.	7
5	**Hazards Identification:** Process Hazards checklists, Hazards surveys, hazards and operability studies, safety reviews.	6
6	**Hazard Assessment:** Failure distribution, failure data analysis, modeling for safety, safety training, emergency planning ad disaster management, case studies	8

8. **Books:**

(B) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1.	Crawl D.A. and Louvar J.A., "Chemical Process Safety Fundamentals with Applications," 4thEd.,Prentice Hall.	2020

(C) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1.	Lees, F. P., "Loss Prevention in Process Industries", Vol.1 and 2, 4th Ed., Butterworth.	2012
2.	Wentz, C.A., "Safety Health and Environmental Protection," McGraw Hill.	1998

1. **Subject Code: 22CHP306** **Course Title: Mass Transfer Lab**
2. Contact Hours: L: 0 T: 0 P: 2
3. Credits: 1 Semester: V
4. Pre-requisite: Nil.
5. Course Objective: Student get hands on practice of conducting various mass transfer operation such as distillation, absorption, liquid-liquid extraction, adsorption, determine the efficiency of separation process and analyze the ratio results.
6. Course outcome: Upon completion of this course, the students will be able to:
   i. Conduct mass transfer experiments-distillation, absorption, extraction, drying, mass transfer coefficient etc.
   ii. Development practical skills to collect data, calculate mass transfer efficiency and analyze the results.

7. Details of Course:

Experiment No.	Objective	Contact Hours
1.	To study the operation of a batch cooling crystallizer experimentally, find the yield of sodium thiosulphate crystal in the batch crystallizer and to verify the material balance.	3
2.	Determination of loss of cooling water due to the evaporation in a cooling tower under given operating conditions.	3
3.	Determination of stage efficiency of the flash vaporization unit for separation of a liquid mixture under given operating conditions.	3
4.	To study the hydrodynamic characteristics of a given packed column operated with counter current flow of gas and liquid (a) to plot log ΔP vs log G', and locate the loading and flooding region.	3
5.	Determination of gas phase mass transfer coefficient under given operating condition in a wetted wall column.	3
6.	Separation of methanol water mixture by bubble cap distillation column and estimate the composition of the low boiling component in the distillate and the bottom product, determine the column efficiency using McCabe-Thiele method.	3
7.	To plot the rate of batch drying curve for a given material under constant drying conditions in a tray dryer	3
8.	Determination of gas-phase convective mass-transfer coefficient by sublimation of a spherical naphthalene ball	3
9.	Determination of solid-liquid mass transfer coefficient for dissolution of a cylindrical rod shaped benzoic acid in water.	3
10.	To determine the efficiency of solid liquid extraction(leaching) in a packed bed extraction column.	3
11.	Packed bed distillation column for separation of MVC from	3

	binary mixture.	
12.	Study of hydrodynamics in packed bed column	3
13.	Study of vapor-liquid equilibrium	3
14.	Estimation of mass transfer coefficient in wetted wall column	3

8. **Books:**

(A) Text Books

S.No.	**Authors / Name of Book / Publisher**	**Year of Publication**
1	Treybal, R. E., "Mass Transfer Operations," 3rd Ed., McGraw Hill, Singapore.	1980
2	McCabe, W.L., Smith, J.C. and Harriott, P. Unit Operations of Chemical Engineering. McGraw-Hill, New York.	1993

(B) Reference Books

S.No.	**Authors / Name of Book / Publisher**	**Year of Publication**
1	King, C. J., "Separation Processes," 2nd Ed., Tata McGraw Hill, New Delhi.	1982

1. Subject Code:22CHP307 Course Title: Process Instrumentation and Control Lab

2. Contact Hours: L:0 T:0 P:2

3. Credits: 1 Semester: V

4. Pre-requisite: Nil.

5. Course Objective: To make the students understand basic applications of process control for controlling various processes used in industries

6. Course Outcomes: Upon completion of this course, the students will be able to:

i. Understand the dynamics of various processes
ii. Understand the applications of feedback controllers
iii. Design and tune P, PI, PID controllers

7. Details of Course:

Experiment No.	Objective	Contact Hours
1.	Study of First order Tank level Dynamics	2
2.	Study of Control Valve Characteristics, to obtain Control value Flow Co-efficient (Cv) and hysteresis	2
3.	Study of First-order dynamics of mercury thermometer	2
4.	Study of dynamic response of mercury thermometer to sinusoidal/on-off change in surroundings temperature	2
5.	Study of second order Process Dynamics of U-Tube Manometers	2
6.	Study of second order Process Dynamics of U-Tube Manometers for different manometric fluids	2
7.	Study of Flow Control trainer to study the on-off, P,PI, PID control	2
8.	Study of Process Dynamics of a Two-Tank Noninteracting System	2
9.	Study of Process Dynamics of a Two Tank Interacting System	2
10.	Study of temperature Control trainer to study the P,PI,PID control	2
11.	Study of Ziegler–Nichols Tuning Technique to identify the best value of Kc, τ_I, τ_D for a PID controller.	2
12.	Study of Cohen Coon tuning technique to identify the best value of Kc, τ_I, τ_D for a PID controller	2
13	Cascade Control Trainer	2
14	Flow Control Trainer	2
15	Pressure Control Trainer	2

8. Books:

(B) Text Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Coughanowr, D. R., LeBlanc, S.E., "Process Systems Analysis and Control", 3rdEd., McGraw Hill.	2009

(C) Reference Books

S.No.	Authors / Name of Book / Publisher	Year of Publication
1	Stephanopoulos, G., "Chemical Process Control", PHI, New Delhi.	1984
2	Luyben, W. L., "Process Modeling, Simulation and Control for Chemical Engineers," 2ndEd., McGraw Hill.	2013
3	Bequette, B.W., "Process Control - Modeling, Design and Simulation," Pretice Hall	2003
4	Seborg, D.E., Edgar, T.F., Mellichamp, D.A., Doyle III, F.A., "Process Dynamics and Control," 3rdEd., Wiley.	2010